Science Convention

1920

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THE FORTY-FIRST ANNUAL MEETING OF THE INDIAN ASSOCIATION FOR THE CULTIVATION OF SCIENCE, HELD ON FRIDAY, THE 20TH SEPTEMBER, 1918, AT 6 P.M.

PRESENT :—

Sir Gooroo Dass Banerjee, KT., M.A., D.L., Ph.D.,
Vice-President (*in the Chair*),
Prof. C. V. Raman, M.A.,
Rai Bahadur, Dr. Chunilal Bose, Rasayanacharyya, I.S.O., M.B., F.C.S.,
Rai Girish Chandra Chaudhury, Bahadur, B.L., Subjudge (*Retired*),
Rai Krishna Chandra Banerjee, Bahadur, B.A., C.E., &c.,
Babu Profulla Nath Tagore,
" Jyotish Chandra Pal, M.A., B.L.,
Dr. Rasik Lal Datta, D.SC.,
Prof. Nibaran Chandra Roy, M.A.
" Sudhansukumar Banerjee, M.SC.,
" Hem Chandra Das Gupta, M.A., F.G.S.
Babu Asutosh De,
Dr. Amrita Lal Sircar, L.M.S., F.C.S.

VISITORS :-

Babu Tarak Chandra Datta,
Babu Kunja Behary Seal,
Mr. H. H. Abdul Razzack,
Prof. T. K. Chinmoyanandam, M.A.,
Mr. Sachindra Nath Mukherjee, M.A., B.L.,
Prof. Suresh Chandra Datta, M.SC.
" Raj Kumar Sen, M.SC., F.C.S.,
" Sisher Kumar Mittra, M.SC.

Besides the above gentlemen, the meeting was largely attended by the students of the Association and several other local colleges.

The Proceedings of the last Annual Meeting were confirmed.

The Chairman then asked the Honorary Secretary to read the report of the Committee of Management for the last year.

Report for the year 1917.

1. The Committee of Management beg to submit the following report showing the work done by the Association during the year under review

2. The scientific work of the Association continued to flourish and develop. A significant departure from established practice was made necessary by the growth of the scientific output of the Association and of the wider interest taken in its proceedings. For several years past, the Annual General Meeting of the Association had been held in the month of November, and had gradually come to be regarded as an event of considerable importance by the members and scholars interested in its scientific work The practice at the Annual Meetings had been first to transact general business and to consider the report and accounts for the previous year, and then to pass on to the sectional meetings at which scientific papers were read It was felt that this arrangement was not quite satisfactory, as it restricted the time available for the reading and discussion of scientific papers, and also delayed the consideration of the previous year's report and accounts till the following cold weather It was accordingly arranged to separate the business and the scientific meetings, and to hold the former in July The scientific meeting was developed into an Annual Science Convention which it is proposed in future to convene regularly in the month of November each year. The first Annual Science Convention was held on the 23rd and 24th of November 1917 and was an unqualified success. The Convention opened with an address by the Hon'ble Justice Sir Asutosh Mookerjee which was listened to by a very large and distinguished audience including the President and Members of the Calcutta University Commission This was followed by the addresses of the Chairmen

of the sectional meetings, and the reading and discussion of original papers. Nine Physical papers, four Chemical papers, and seven Biological papers were on the programme of this Convention. These will be published together in one volume along with this Report.

3. In addition to the Convention, three other scientific meetings were held during the year, and the papers read were incorporated in the Proceedings of the Association of which the third volume appeared during the year under review. The volume extended to 160 pages in print, illustrated by 24 full page plates. The following is a list of the papers that appeared in Vol. III of the Proceedings.

(1) Notes on a Free-living Amœba of a new Species,—by Rai Bahadur Dr Gopal Chandra Chatterjee, M.B.

(2) On the Process of Development of Rohita, Catla, Cerrhina Mrigala in confined waters in Bengal,—by Bepin Behary Das, M.A.

(3) On Aerial Waves Generated by Impact, Part II, --by Sudhansukumar Banerji, M.SC.

(4) On the Diffraction of Light by Cylinders of large Radius.— by Nalinimohan Basu, M.SC.

(5) Disappearance of Volumes by Dissolution of Substances in Water,—by Jitendra Nath Rakshit, F.C.S.

(6) On the Application of Cochineal Stain on Calcite and Aragonite,—by Suresh Chandra Datta, M.SC.

(7) On the Flow of Energy in the Electro-magnetic Field, surrounding a perfectly Reflecting

Cylinder,—by T. K. Chinmayanandam, B.A. (*Hons.*)

(8) On Resonance Radiation and the Quantum Theory—by T. K. Chinmayanandam, B.A. (*Hons.*)

(9) Equilibrium between Copper Salts and Mercury in presence of Chloridion and Bromidion,—by Jnanendra Chandra Ghose, M.SC.

(10) Notes on some Fish Teeth from the Tertiary Bed of Western India,—by Prof. H. C. Das Gupta, M.A., F.G.S.

4. Bulletin No. 15 which is a monograph by Prof. C. V. Raman was to have been published during the year under review, but was unfortunately delayed in its appearance by various circumstances. It is hoped that this will be published in the current year (1918), and that a special publication on "Copper in Ancient India" by Dr. Panchanan Neogi which was taken up in 1917 will also be completed in 1918.

5. A very gratifying event which occurred in the year under review was the endowment of a Research Scholarship in Physics of Rs. 75 a month tenable for two years founded by Kumar Sri Panchanan Mukhopadhyaya, the grandson of Raja Peary Mohun Mukherjee of Uttarpara, President of the Association. The Uttarpara Raj Family has taken a lively interest in the development and welfare of the Association since its foundation. The best thanks of the Association are due to the Kumar for his generosity. This endowment emphasises the fact that research work in various branches of science and the scientific activity of the Association have attracted the attention of the aristocracy of Bengal, and it is hoped that others will generously

come forward to endow more such scholarships. Besides this, the Association has been able to continue its two research scholarships each of Rs. 50 a month in Chemistry.

6. The first recepient of the Kumar Sri Panchanan Mukhopadhyaya scholarship was Mr. T. K. Chinmayanandam, a brilliant graduate from the Madras University, who has more than justified the award of the scholarship by the output of his research. Besides contributing original papers on "The Flow of Energy in the Electromagnetic Field sorrounding a perfectly reflecting Cylinder," and on "Resonance Radiation and the Quantum Theory" to Vol. III of the Proceedings of the Association, Mr. Chinmayanandam has carried out several other interesting investigations since he started work in August 1917. A paper on "The Diffraction of Light by an obliquely held Cylinder" has been contributed by him to the "Physical Review," and an investigation on "Haidinger's Rings in Mica" has been communicated to one of the most eminent of the learned societies of the world. A paper on "The Specular Reflection from Rough surfaces" has been completed and is expected shortly to be published. One of Mr. Chinmayanandam's communications appeared in the well-known journal "Nature" in the issue of December 13, 1917; and the "Philosophical Magazine" of London is also publishing his work.

7. One of our Vice-Presidents, Prof. C. V. Raman, during the year under review, entered upon the duties of the, Sir Taraknath Palit professorship of Physics in the University of Calcutta, and there has been simultaneously a vigorous development of the Calcutta School of Research in Physics, to the activities of which the Association has freely contributed its resources, equipment and personnel. In the twelve months which have intervened between July

1917, and the writing of this report, the number of original investigations in Physics by this school, published or carried nearly to the point of publication, was twenty five and it is hoped that in the near future, the output will improve further. Apart from the work carried by Prof. Raman in stimulating and assisting the work of this school, and in providing the necessary equipment and facilities for its development, a number of investigations have been carried out by him personally, of which perhaps the most interesting is on the explanation of the effect of a mute on the character of the tone of bowed stringed instruments. This has been published in the well-known journal "Nature" (October 4, 1917), and more fully in a recent issue of the "Philosophical Magazine". An interesting observation made in this connection is that the gravest resonance of a violin or cello does not ordinarily exhibit the "wolf-note" phenomenon but may be made to do so by loading the bridge of the instrument. Besides the above, Prof. Raman published three papers in the "Philosophical Magazine" during the year under review, written in collaboration with Babu Ashutosh Dey. Two of these dealt with the subject of Discontinuous Wave-Motion, and one with the Maintenance of Vibrations by a Periodic Field of Force. The latter investigation has since led to very important developments in its application to the absolute measurement of acoustical frequencies.

8. Prof. Sudhansukumar Banerji during the year under review carried on his investigations in the fields of Acoustics and Optics in the Laboratory of the Association, obtaining important results which have been published in the Proceedings. His work on Aerial Waves generated by Impact has also been published in the "Philosophical Magazine". Prof. Banerji's investigations on Optics during the year under review dealt with the Theory of Foucault's

test and the Radiation from the Edges of Diffracting Apertures, and a note by him on this subject appeared in the issue of "Nature," dated 10th May, 1917. This investigation is now receiving fuller publication.

9. Mr. Nalinimohan Basu worked in our Laboratory during the year under review and carried out an important investigation on the Diffraction of Light by Cylinders of Large Radius which has been duly published.

10. Our senior demonstrator Babu Ashutosh Dey has continued his work in the Physical Laboratory in a most efficient manner. Besides assisting Prof. Raman and collaborating with him in his researches, he has also undertaken research work on his own account with very satisfactory results, and it is hoped that these will soon be published in a befitting manner.

11. Among visitors from other parts of India who worked for short periods in the Laboratory of the Association during the year under review and carried out successful investigations should be mentioned specially Prof. Chandi Prasad of Queen's College, Benares, who carried out a research on the Theory of superposed Diffraction Fringes. It is hoped that this will soon be duly published. Mr. Deoras from Nagpur also worked for some time in the Laboratory of the Association. Prof. J. Ray of Krishnath College, Berhampur, has also interested himself in Physical research work and is taking active part in it.

12. On the Chemical side, our research scholars, Babus M. N. Banerji and Jagadindra Nath Lahiri have continued their work. The investigation of the former dealt with the subject of the velocity of chemical reactions, and of the latter on the subject of iodination of organic compounds and the replacement of iodine atoms in phenolic bodies

by nitrogroups. Dr. R. L. Datta has continued to take great interest in the work of the Chemical side and the special thanks of the Association are due to him for the trouble he has taken in organising the Library, preparing a set of Library Rules and cataloguing our books and periodicals.

13. The committee note with great pleasure that of the students, who took up Botany as one of the subjects for the University Intermediate Examination in Science and attended lectures at the Association in the year, 1917, 62 % passed successfully.

14. The regular courses of lectures were delivered at the Association as usual.

15. The subjects lectured upon during the year were as follows :—

Physics, by	Dr. Amrita Lal Sircar, L.M.S., F.C.S., Prof. Nibaran Chandra Ray, M.A., „ Jitendra Nath Sen, M.A
Chemistry, by	Rai Bahadur, Dr Chunilal Bose, I.S.O., Rasayanacharyya, M.B., F.C.S.
Botany, by	Prof. Jyotish Chandra Pal, M.A., B.L., „ Raj Kumar Sen, M.A., F.C.S

16. In continuation of the courses of the session 1916-17, twenty-six lectures were delivered on Physics and Chemistry in January, February and March, of which 4 were by Dr. Amrita Lal Sircar on Physics and 22 by Dr. Chuni Lal Bose on Chemistry.

17. The four lectures delivered by Dr. Amrita Lal Sircar were on General Properties of Matter and embraced the following subjects :—

Boyle's Law,—its verification, and its practical application. Diffusion of gases and laws govering it.

18 The twenty-two lectures delivered by Rai Bahadur, Dr. Chunilal Bose were on non-metals and metals and embraced the following subjects :—

Carbon, its occurrence, allotropic modifications and properties. Oxides of carbon; carbon monoxide; its preparation and properties; carbon dioxide, its occurrence, preparation, properties and tests; carbonates and bi-carbonates. Marsh gas. Ethyline. Acteyline. Coal-gas. Structure of Flame. Bunsen Burner. Cyanogen compounds. Hydrocyanic acid and cyanides. Sulphur, its occurrence, manufacture, allotropic modifications and properties. Manufacture of sulphuric acid; its properties and tests; sulphates and bisulphates Hyposulphurous acid and hyposulphites. Sulphuretted hydrogen, its preparation, properties and tests. Sulphides. Carbon-disulphide. Phosphorus, its allotropic modifications, its manufacture. Oxides and oxy-acids of phosphorus, phosphates, phosphoretted hydrogen, and phosphides. Arsenic, its compounds and tests. General characters and classification of metals. Potassium, sodium, ammonium, calcium, barium, strontium, magnasium, zinc, aluminium—their occurrence, extraction, properties, compounds, uses and tests. Cast iron, wrought iron, steel, —their preparation, properties and uses. Compounds of iron and their tests. Mercury, its occurrence, preparation and properties. Mercurous and mercuric compounds, and their tests. Lead, its extraction, compounds and tests. Silver, its extraction, compounds and tests.

19. The Required number of lectures delivered by Profs. Jyotish Chandra Pal and Rajkumar Sen were in continuation of their courses in Botany and they were intended for the students preparing for the I. A. and I. Sc. Examinations of the Calcutta University.

Regular Practical classes in Botany for the 2nd year I. A. and I. Sc. students were held under Profs. Jyotish

Chandra Pal and Raj Kumar Sen and Demonstrator Babu Sarat Chandra Roy.

20. The session 1917-18 was opened on the 6th of July with an Introductory Lecture on "The History and Chemistry of a Piece of Chalk" by Rai Bahadur, Dr. Chunilal Bose. There was a very large and appreciative audience. The lecture was fully illustrated with the projection of lantern slides.

For various unforeseen reasons the Calcutta University was compelled to put off its examinations till very late this year, in consequence of which all the colleges delayed in opeing their First Year classes. The professorial staff of the Association also thought it fit to put off lecturing on Physics and Chemistry until students of the I year and III year classes from the local colleges could join the Association. So, though the session opened early in July, regular classes in Physics and Chemistry commenced late in November. Second year Botany classes, however, were not stopped and continued to be held regularly since the opening of the session.

21. The lectures delivered on Physics and Chemistry, up to the end of December were 12 in number. Of these two lectures were delivered by Prof. Jitendra Nath Sen on Sound, two by Prof. Nibaran Chandra Roy on Electricity and eight by Dr. Chuni Lal Bose on Chemistry. Thus altogether there were 38 lectures delivered on Physies and Chemistry during the whole year 1917.

22. The two lectures delivered by Prof. Jitendra Nath Sen on Sound embraced the following subjects :—

Introductory lecture in sound. Production and Propa gation of sound.

23. The two lectures delivered by Prof. Nibaran Chandra Roy on Electricity embraced the following subjects :—

Introductory lecture in Electricity. Electrical Induction.

24. The eight lectures delivered by Rai Bahadur Dr. Chunilal Bose on Chemistry were on non-metals and embraced the following subjects :—Definition and scope of chemistry. Physical and chemical changes. Indestructibility of matter. Elements and Compounds. Atoms and molecules. Symbols and formulæ, Atomic weights. Chemical notation. Laws of chemical combinations. Chemical Balance. Weights and measures. Oxygen—its occurrence, preparation and properties Tests of oxygen. Catalysis. Oxides.

25. Many students from various colleges including the Medical College, attended the Practical Chemistry class for preparing themselves to appear at their respective University Examinations. It is very gratifying to note that these students did creditably in the examinations. The success of the department is mainly due to Prof. Haradhan Ray, M.A., F.C.S., who is in charge of the Practical classes.

26. A very large number of students attended the Botany classes held during the year under review. The success of the department is due to the labour on the part of those who are responsible for this section.

The required number of lectures on Botany were delivered by Profs. Jyotish Chandra Pal and Raj Kumar Sen to the 1st and 2nd year students preparing themselves for the I.A. and I. Sc. Examinations of the Calcutta University.

The practical work in Botany was conducted by Profs. Jyotish Chandra Pal and Rajkumar Sen and the Demonstrator Babu Sarat Chandra Roy.

27. The following periodicals were subscribed for the library viz :—

(1) Scientific American with supplement.
(2) Science.
(3) Nature.
(4) Science Abstract, Sections A and B.
(5) American Journal of Science.
(6) Philosophical Magazine.
(7) Botanical Gazette.
(8) Annals of Botany.

28. The Committee have to acknowledge with thanks the following presentations to the Library :—

From the Smithsonian Institution (U. S. A.)

1. Notes on the Embryology and Larval Development of five species of telostean fishes, Vol. XXXIV. Doc. 831.
2. Annual Report of the Smithsonian Institution, 1915.
3. Proceedings of the United States National Museum, Vol. 50.
4. Bulletin of the Bureau of Fisheries, Vol. XXXIV, Doc. 829. 823, and 832.
5. Alaska Fisheries and Fur Industries in 1915, Doc. No. 834.
6. Annual Report of the Commissioner of Fisheries, 1916.
7. The fishes of the Streams, Tributary to Tomales Bay, California.
8. Pacific lord fisheries, Doc. No. 830.
9. Pacific Salmon fisheries, Doc. No. 889.

From the Cambridge Philosophical Society.

1. Proceedings of the Cambridge Philosophical Society, Vol. XIX, pts. I, II. and III.

From the Royal Academy of Sciences, Amsterdam.

1. Proceedings, Vol. XIX. No. 2, 1916; Nos. 3, 4, 5, 6, 7, 8 and 9, 1917; Vol. XX. No. 1, 1917.
2. Verhandengen of the Royal Academy of Sciences, Amsterdam, Tweede Sectic Deel XVIII, No. 6; Deel XIX No. 1. Enserte Sectic, Deel XII Nos. 1 and 2.

From the Imperial Academy of Sciences, Stockholm.

1. Arkiv for Matematik, Astronomi och Fysik, Band 11, Hafte 1 2 and 3.

From the Mathematico-Physical Society, Tokyo, Japan.

1. Proceedings of the Tokyo Mathematico-Physical Society. 2nd Ser., Vol. VIII, Nos. 21 and 22, 1916; Vol. IX., No. 20. Nos. 2-9., 1917.
2. Back volumes, 2nd Ser., Vol. VII. Nos. 1-4 and 22.

From Manchester Literary and Philosophical Society.

1. Memoirs and Proceedings of the Manchester Literary and Philosophical Society. Vol. 60, pt. III, 1915-16. Vol. 61 pt. 1, 1916-17.

From the Royal Danish Academy of Sciences, Copenhagen, Denmark.

1. Oversight over Det knowledge Danske 1916, No. 3.

From the University of Illinois.

1. University of Illinois Bulletin, Vol. XIV. Nos. 46, 51 and 35, 1917.

From the Faraday Society, London.

1. Transaction of the Faraday Society, Vol. XII, pts. 1, 2 and 3. June, 1917

From the Franklin Institute.

1. Journal of the Franklin Institute, Vol. 183. Nos. 1-6; Vol. 184. Nos. 1-4.

Bulletin of Roure-Bertrand Fils of Grasse.

1. Bulletin of Roure-Bertrand Fils of Grasse, Series 3, Nos. 8 and 9, 1913 and 1914.

From the American Geograptical Society.

1. The Geographical Review, January, Nov., December, 1916; Jan., March to Sept. 1917.
2. Bulletin of the American Geographical Society. Vol. XLVII. Nos. 8 and 12. 1915.

From the South African Association for the Advancement of Science.

1. The South African Journal of Science, Vol. XIV, Nos. 2-5, 1916, Nos. 1 and 6-11, 1917.

From the Government of India.

1. Monthly Weather Review, June to October, 1916.
2. Patent office Journal, January to Sept., 1917.
3. Records of the Geological survey of India, Vol. XLVII, p.t. 4. Vol. XLVIII. pts. 1 and 2.

4. Rules Regarding Magnetic Declination for the guidance of Court Surveyors and others.
5. Report on the Administration of the Meteorological Department of the Government of India in 1916-17,
6. India Weather Review Annual Summary, 1915.
7. The Indian Trade Journal for the year, 1917.
8. India Daily Weather Report for the year, 1917
9. Gazette of India for the year, 1917.

From the Government of Bengal.

1. Calcutta Daily Weather Report for the year 1917.

From the Government of Bombay.

1. Reports of the Chemical Analyser to Government Bombay and the Chemical Analyser for Sind for the year, 1916.
2. Annual Report of Lunatic Asylums for the year, 1916.
3. Triennial Report on civil Hospitals and Dispensaries, 1914-16.

From the Government of Mysore.

1. Meteorology in Mysore for 1915.
2. Report on the Rainfall Registration in Mysore, 1915.

From the Agricultural Research Institute, Pussa.

1. Memoirs of the Department of Agriculture in India, Vol. IV, No. 6. Vol. V No. 1. Chemical Series. 1916. Vol. V. Nos. 3, 4 and 11. Entomological Series. 1917.
2. Agricultural Research Institute, Bulletin Nos. 1, 4, 15, 30, 32, 33, 36, 42, 43, 60, 64-66, 68, 75.
3. Agricultural Journal of India. Vol. II pt. 1. 1917. Vol. VI pt. III. 1911. Vol. XII. pt. II, III, IV, 1917.
4. The Report of the Imperial cotton Specialist, 1916-17.

From the Bureau of Standards (Washington).

1. Circular of the Bureau of Standards, Nos. 61, 62 and 63.
2. Technologic Papers of the Bureau of Standards, No. 80.
3. Bulletin of the Bureau of Standards, Vol. 13, No. 3.

From the Indian Institute of Science, Bangalore.

1. Journal of the Indian Institute of Science, Vol. I to XIX.

From the University of Pennsylvania, Philadelphia.

1. The Musuem Journal, Vol. VII. Nos. 1—4. 1916.

From the Editor.

1. Indian Engineering for the year 1917.

From Dr. Amrita Lal Sircar.

1. Calcutta Journal of Medicine for the year, 1917.
2. বিজ্ঞান for the year, 1917.

From Prof. C. V. Raman.

1. Physical Review, Jan., March, April, June, July, Sept., Nov. Dec., 1917.

From Indo-American Association.

1. Hindusthani Student, Vol. III, Nov. and Dec. 1916. February to May, 1917.

Miscellaneous.

1. Asiatic Review, Jan.-April, July and August, 1917.
2. Elements of Wave Theory of Light, by J. N. Sen, Prof. of Physics, City College, Calcutta
3. Papers on Hindu Mathematics and Astronomy, by Probodh Chandra Sen Gupta, M.A.
4. Bulletin of the Calcutta Mathematical Society, Vol. IV—VII 1912-13 to 1915-16.

From the Asiatic Society of Bengal.

1. Journals and Proceedings of the Asiatic Society of Bengal, New Series, Vol. XIII. Nos. 1—5.
2. Memoirs of the Asiatic Society of Bengal, Vol. V., No. 5 pp. 195-205 ; Vol. VI, pp. 75-155, Vol. VI, pp. 157-182.

29. On the 31st of December, 1917, the Association had in the custody of the Bank of Bengal the Government securities of the value of Rs. 2,10,400-0-0 for the General Fund, Rs. 6,000-0 for the Ripon Professorship Fund, Rs. 500-0-0 for the Nikunja Garabini Prize Fund, a floating balance in the Bank of Rs. 5,447-1-5 and a cash balance in the office of Rs. 1,184-7-10 amounting in all to Rs. 2,23,531-9-3.

On the 31st of December, 1916, the Association had in the custody of the Bank of Bengal the Government securities of the value of Rs. 2,04,400-0-0 for the General Fund Rs. 6,000-0-0 for the Ripon Professorship Fund, Rs. 500-0-0 for the Nikunja Garabini Prize Fund, a floating balance in

the Bank of *R*s. 2,755-3-11 and a cash balance in the office of Rs. 911-3-3 amounting in all to Rs. 2,14,566-7-2.

30. Rai Durga Dass Bose, Bahadur made a gift of Rupees five thousand by his will, to the Association. This was paid by his widows in Govt. Promissory Notes. The Committee in gratefully accepting the gift conveyed their thanks to the widows and informed them that the name of the donor will be associated with the gift.

31. The thanks of the Association are due to His Highness the Maharaja of Cooch Behar, G.C.I.E. for his generous contribution of Rs. 100 per month in aid of the establishment of a permanent professorship and also to the following members who were kind enough to continue their annual subscriptions :—

Raja Peary Mohan Mukerjee, C.S.I.,
Babu Nirmal Chandra Chandra, M.A., B.L.

32. The thanks of the Association are also due to their Honorary Lecturers, Dr. Amrita Lal Sircar, Prof. Jitendra Nath Sen and Prof. Nibaran Chandra Ray; to their Honorary Engineers, Babu Khetter Mohan Bose and Rai Krishna Chandra Banerji Bahadur, to their Honorary Legal Adviser, Babu Jatindra Nath Bose; to their Honorary Auditor, Babu Ishan Chandra Bose; to their Honorary Secretary, Dr. Amrita Lal Sircar; to their Honorary Asst. Secretary Babu Nilmani Coomer for their gratuitous services.

33. The thanks of the Association are also due to the Editors of the Indian Mirror, the Bengalee, and the Statesman for gratuitously publishing in their columns announcements of the lectures delivered at the Association and the daily meteorological observations recorded at the observatory of the Association.

34. The annual examination of the candidates for prizes and medals was held in December 1917. The examination was conducted by Prof. Jitendra Nath Sen and Dr. Amrita Lal Sircar in Physics and by Rai Bahadur Dr. Chuni Lal Bose in Chemistry. The examination was both theoretical and practical. Three students came out successfully and will be awarded medals and prizes. Their names are given below in order of merit :—

Babu Manic Lal Das,
Joykissen Mukherjee Gold Medal.

„ Profulla Chandra. Nandi,
Temple Silver Medal.

„ Bankim Chandra Roy,
Jatindra Chandra Prize.

34. The annual Examination of the I year and Test Examination of the II year Botany classes (Session 1917-18) were held in due time. The first three students of each class will be awarded prizes. Their names are given below in order of merit :—

Test Examination.

II year.

I. Babu Suprakash Sen Gupta,
II. „ Nagendra Nath Sen,
III. „ Pulin Behary Ghosh.

Annual Examination.

I year.

I. Babu Sudir Kumar Chakraverty,
II. „ Sashadhar Goswami,
III. „ Sri Ranjan.

The following resolutions were unanimously carried :—

Proposed by Rai Bahadur, Dr. Chunilal Bose.

Seconded by Prof. Nibaran Chandra Roy.

That the Report of the Committee of Management be adopted and that the Accounts be passed.

In proposing the above resolution Rai Bahadur Dr. Chunilal Bose said :—

MR. CHAIRMAN AND GENTLEMEN :—

The Science Association has just completed another year of its existence and the Honorary Secretary has presented to us a short but illuminating report of the work done by the Association during the year 1917. You have gone through the report or at least you have listened to it read at this meeting. I think you will all agree with me when I say that there is much in the report over which we can truly rejoice. The report is a record, I should say, of steady and sustained effort on the part of the Association for the realisation of its ultimate object, and we all know what that object is, namely, the cultivation of science in the widest application of the term. You have learnt from the report that the research work during 1917 made satisfactory progress. We strengthened our staff last year by the appointment of a distinguished graduate of science of the Madras University, Mr. Chinmayanandam, as one of our research-scholars. The Committee was very hopeful at the time that the appointment would bring forth good results. I have no hesitation to say that our young research-scholar has fulfilled the best expectations of the Committee (cheers). You have heard the Secretary to say that in the course of a single year, Mr. Chinmayanandam has been able to write four papers on original work done by him in this laboratory,

and his last paper on Haidinger's Rings in mica is of exceptionally good merit. It has elicited approbation from quarters best able to judge its merit. You will be glad to hear that, that paper has been communicated by Dr. G. T. Walker, Director-General of the Meteorological Observatories in India, to the Royal Society of London. This is an honour which is coveted by the greatest scientists all over the world. I heartily congratulate my young friend on the brilliant results of his work and I also congratulate this Association on its happy selection. You have also heard from the report that Mr. Chinmayanandam will be awarded the Woodburn Research Medal this year. With the prize, he carries with him our best wishes. He is one of those whose brightness can hardly escape the keen eyes of the world. You know he has already been given one of the prize-appointments in the University College of Science. His joining the College of Science would have meant a great loss to us, had it not been for the fact that, like my friend on the right, Mr. Raman, Mr. Chinmayanandam will continue his work in this Association also. So we all feel happy at his getting such a prize appointment, and at the same time, we have no cause for regret, because the arrangement would not make us suffer in any way.

It is hardly necessary for me to speak about my friend, Mr. Raman, who continued his investigations as usual during the year under review. He has made several valuable additions to our stock of knowledge on the subject of stringed instruments. He was ably assisted by one member of our permanent staff, Mr. Asutosh Dey, and they jointly produced three original papers which have since been published in the Philosophical Magazine. Mr. Dey also conducted original investigations on his own account and his paper will soon be published by this Association. I think I ought to mention here that our Honorary Secretary, when

he found that Mr. Dey was really doing such useful original work, has very wisely relieved him of his routine duties, so that Mr. Dey can now devote nearly the whole of his time to the pursuit of research-work. Prof. Sudhansukumar Banerjee who is the happy recipient of Dr. Mahendra Lal Sircar Research Gold Medal of this year, did a considerable amount of very useful work in his own line (Applied Mathematics) in this laboratory. I do not think I am privileged to make an announcement which you will soon see in the papers. He has a very high honour in store for him for doing important original work. Mr. M. N. Banerjee and Mr. J. Lahiri have done good and useful work, on the chemical and Mr. N. M. Bose on the physical sides of the laboratory. So far as quality is concerned, the output of chemical work is satisfactory. But if you take quantity into your consideration, the physical side has out-balanced the chemical side. Dr. Rasik Lal Datta is taking great interest in this Association and his name and fame are not confined within the limits of India but have gone abroad. I hope he will take greater interest in the chemical side and we hope to see chemical work increase in volume next year.

The most importnant event of the year was the holding of the Science Convention under the auspices of this Association. The Convention met for two days and a number of original and most interesting papers on Physics, Chemistry and Biology were read at its two sittings. I congratulate the Committee of the Association on their decision to make the Convention an annual institution, and I hopefully look forward to its next sitting in coming November. I hope there be a large and appreciative attendance and a larger number of interesting papers will be read. This Convention, I hope, will be a common meeting place for people engaged in various scientific pur-

suits all over India and will form a focus of scientific knowledge and culture which will no longer remain disconnected and scattered in the different parts of the country.

I wish to mention one matter passingly, which does not fall within the year under report. It has an important bearing on the future welfare of this Association and I hope you will excuse me for making reference to it in today's proceedings. I mean the founding of a triennial Research Gold medal in honour of the late Dr. Mahendra Lal Sircar, the illustrious Founder-Secretary of the Association (cheers) by his worthy son, Dr. Amrita Lal Sircar. The first happy recipient of that medal is our friend, Mr. Sudhansukumar Banerjee. I cannot but admire the far-sightedness of Dr. Sircar in not limiting the competition for this prize to Bengal alone but keeping it open to all students of science throughout India. The institution of this medal will, I am sure, stimulate research-work all over India. This Research medal in the name of Dr. Mahendra Lal Sircar will, I hope, carry with it the same reputation and honour as similar medals instituted by the great scientific societies of the West, such as the Royal Society's medals in England, carry with them (cheers). Our grateful thanks are due to Dr. Amrita Lal Sircar for the institution of this valuable research-prize.

Only one word more and I am done. If you have followed the report in detail, you must have noticed that Dr. Amrita Lal Sircar has not only managed the Association efficiently, but he has done it also economically (cheers). After meeting all the expenses—and the expenses have been great on account of the prosecution of research work in this Institution—he has been able to save a sum of Rs. 6,000, which has been added to the reserved fund. It speaks well of his able and economical management

of the Association and I would ask you to join me in offering our very best thanks to the Honorary Secretary for his able and disinterested services.

With these few observations, Sir, I beg to move the adoption of the report for the year 1917 with the audited accounts.

II. Proposed by Prof. Hem Chandra Das Gupta.
Seconded by Dr. Rasik Lal Datta.

That the office-bearers of the Association for the current year be as follows:

OFFICE-BEARERS.

PRESIDENT:

RAJA PEARY MOHUN MUKHERJEE, C.S.I., M.A., B.L.

VICE-PRESIDENTS:

SIR GOOROO DASS BANERJEE, Kt., M.A., D.L., Ph.D.,
HON'BLE JUSTICE SIR ASUTOSH MOOKERJI, Kt., Saraswati,
Shastra-Vachaspati, C.S.I., M.A., D.L., D.SC., F.R.S.E., F.R.A.S.,
Dr. P. C. RAY, C.I.E., D.SC., PH.D.,
Prof. C. V. RAMAN, M.A.,
Dr. B. L. CHAUDHURI, D.SC., F.R.S.E., F.L.S.

HONORARY AUDITOR:

BABU ISHAN CHANDRA BOSE, M.A., B.L.

HONORARY LEGAL ADVISER:

BABU JATINDRA NATH BOSE, M.A., B.L.

HONORARY ENGINEERS:

RAI KRISHNA CHANDRA BANERJEE BAHADUR, B.A., A.M.I.C.E.,
BABU BHABADEV CHATTERJEE, L.C.E.

HONORARY LIBRARIAN:

Dr. RASIK LAL DATTA, D.SC.

HONORARY SECRETARY:

DR. AMRITA LAL SIRCAR, L.M.S., F.C.S.

HONORARY ASST. SECRETARY:

BABU NILMANI KUMAR.

III. Proposed by Prof. Jyotish Chandra Pal.

Seconded by Dr. Sudhansukumar Banerjee.

That the Committee of Management for the current year be constituted as follows:

THE COMMITTEE OF MANAGEMENT.

PRESIDENT:

Raja Peary Mohun Mukherjee, C.S.I., M.A., B.L., *Ex Officio.*

VICE-PRESIDENTS:

Sir Gooroo Dass Banerjee, KT., M.A., D.L. Ph.D.. *Ex Officio,*
Hon'ble Justice SIR Asutosh Mookerjee, KT., Saraswati, Shastra-Vachaspati, C.S.I., M.A., D.L., D.SC., F.R.S.E., F.R.A.S., *Ex Officio.*
Dr. P. C. Rây, C.I.E., D.SC., PH.D., *Ex Officio,*
Prof. C. V. Raman, M.A., *Ex Officio,*
Dr. B. L. Chaudhuri, D.SC., F.L.S., F.R.S.E., *Ex Officio.*

MEMBERS:

H. H. The Maharaja of Cooch Behar, G.C.I.E.,
Babu Surendra Nath Banerjee, B.A.,
Babu Ishan Chandra Bose, M.A., B.L., *Ex Officio,*
Dr. Chandra Sekhar Kali, L.M.S.,
Mahamahopadhyaya Hara Prasad Shastri, C.I.E., M.A., B.L.,
Rai Girish Chandra Chaudhury, Bahadur, B.L., Sub-judge (retired),
Rai Bahadur, Dr. Chunilal Bose, I.S.O., Rasayanacharyya, M.B., F.C.S.,
Babu Devendra Nath Mitra, B.L.,
" Bipin Behari Ghosh, B.L.,
" Atul Chandra Dutt, M.A., B.L.,
Rai Radha Charan Pal, Bahadur,
Prof. Kali Prasanna Chattoraj, M.A.,
Rai Saheb, Abhilash Chandra Mukherjee,
P. N. Mukherjee, Esq., M.A.,
Dr. Girindra Nath Mukherjee, B.A., M.D.,
S. Taj Mohammad, Esq., M. A., M. SC.,
Dr. Ganesh Prosad, M. A., D. SC.,
C. Subrahmanya Ayyar, Esq., B.A.,
Babu Jatindra Nath Bose, M.A., B.L., *Ex Officio,*
Babu Jyotish Chandra Pal, M.A., B.L.,
Babu Nirmal Chunder Chunder, M.A., B.L.,
Dr. Rasik Lal Datta, D.SC., *Ex Officio.,*

D

Prof. Hem Chandra Das Gupta, M.A., F.G.S.,
Kumar Sree Panchanan Mukhopadhyaya,
Rai Krishna Chandra Banerjee Bahadur, B.A., A.M.I.C.E., *Ex Officio*,
Babu Bhabodev Chattopadhyaya, L.C.E., *Ex Officio*,
Babu Nilmani Kumar, *Ex Officio*,
Dr. Amrita Lal Sircar, L.M.S., F.C.S., *Ex Officio*.

IV. Proposed by Dr. Amrita Lal Sircar.
Seconded by Prof. C. V. Raman.

That Mr. H. Parameshwaram be elected as an Ordinary Member of the Association.

The Honorary Secretary announced the names of the following gentlemen who became Life-Members of the Association :—

1. **Babu Profulla Nath Tagore,**
2. **Lieut. Monmohon Coomer, I. M. S.**

Prof. C. V. Raman announced the endowment of Dr. Mahendra Lal Sircar Research (gold) Medal.

In announcing the endowment of Dr. Mahendra Lal Sircar Research Medal, Prof. C. V. Raman said :—

Sir Gooroo Dass Banerjee and gentlemen,

It is a long time since I have had to perform a duty so pleasant as the one that now falls to me, a duty which is a real pleasure as it is connected with the memory of the man who practically created the Institution in which we have met this evening, and for whose work and character I have very great reverence,—Dr. Mahendra Lal Sircar. I was not fortunate enough to have met and known Dr. Mahendra Lal Sircar during his life-time as my first visit to Calcutta was in the year, 1907. But, believe me, gentlemen, the ten years I have worked in the Institution to which Dr. Mahendra Lal Sircar consecrated his life have enabled me to come into almost physical

contact with the personality of the man, and to appreciate his wonderful enthusiasm for scientific knowledge, and what was perhaps even greater, his devotion to the service of his country. Again and again, I have felt that Dr. Mahendra Lal Sircar's self-sacrificing labours in the cause of science deserve to be remembered and cherished and should never be allowed to be forgotten in this country. It is therefore a very great pleasure to see that steps are now being taken to secure this object. Our present Honorary Secretary, Dr. Amrita Lal Sircar, has come forward to create an endowment in favour of the Association, and it is most fitting that the object of the endowment is to associate the memory of his father in a permanent manner with the progress of scientific research in India. For forty years, Dr. Mahendra Lal Sircar worked strenuously in the hope to see the day when his countrymen would worthily contribute their share to the advancement of scientific knowledge and not be content merely with learning at the feet of the rest of the world. This hope was the mainstay of his life, and sustained his efforts through all the years when his work first opposed, then ignored and treated with cold indifference and even with contempt. The work of a strong man does not die with him, and Dr. Mahendra Lal Sircar was a strong man, perhaps not physically strong but strong in the intellect and the spirit, and the work he did to enable India to take her place in the world of knowledge is today bearing fruit. The endowment by Dr. Amrita Lal Sircar of a medal for scientific research to be associated with the name of his father is not merely an act of filial piety, but an act which will impart an impetus to the progress of Science in India, and advance the great aims underlying Dr. Mahendra Lal Sircar's life and career. It is thus an act most heartily to be welcomed. It is now my duty to announce to you the exact terms of the award :—

(1) That the medal be designated the "Dr. Mahendra Lal Sircar Research Medal."

(2) That the medal be of gold of the value of Rs. 315 and to bear the title of the medal on the obverse and the name of the receipient and the word "for researches ...." on the reverse.

(3) That the medal be awarded triennially at the discretion of the Committee of Management to such person as they may determine, subject to the condition that the receipient during the three years prior to the award should have carried out scientific work of a markedly original and meritorious character in India.

(4) That the award be subject to the further condition that the work referred to in para 3 should have been presented to the Association for publication in its proceedings and remains its enclusive property.

These terms have been most carefully drawn up and will I think substantially advance the objects of the endowment. Gentlemen, it is not rare in this country to find instances of men even in high positions promising gifts and then allowing their promises to remain unfulfilled. I am glad that the present endowment is a solid performance, and not merely a promise which might vanish into thin air. Dr. Amrita Lal Sircar has handed to me here a Government security of the face value of Rs. 3,000, the interest of which is sufficient to meet the cost of the medal to be awarded periodically. I do not think myself that the monitary value of a medal has a very great attraction for a man of science. It is rather the traditions which attach to the medal and the standard of work which its award connotes that fix its real value in the eyes of a man of science. A research medal, be it merely of bronze, associated with the name of Dr. Mahendra Lal

Sircar confers a distinction which cannot be enhanced by altering the composition of its metal. But the glitter of gold has a proverbial influence on the worldly-minded. Even the man of science is not perhaps exempt from it and the fact that the medal now endowed is of substantial value will not detract from its merit. One of the conditions of the endowment is that the receipient of the medal should have carried out scientific work of a markedly original and meritorious character. The high standard thus enforced will enhance the distinction conferred by the award of the medal, and will I hope have a stimulating effect on our scientific workers. The award of the medal is to be triennial, and I think this is a wise provision, as three years is none too long a period for the planning and carrying out of a really important series of investigations. It is for work of a really substantial character that the medal is intended to be a recognition and the award of a medal of a smaller value at more frequent intervals will be less suitable in view of this object. The award can be made to scientific workers in any part of India. The last condition of the endowment is very significant and in my opinion most important. This requires that the work for which the medal is awarded should have been presented to the Association for exclusive publication in its proceedings. In my view, the time has come when work of a really important character can be carried out and published exclusively in the proceedings of the Association, and receive adequate recognition from speciallists abroad. There are or ought to be no international barriers in the realm of scientific knowledge, and I can quote several instances within my personal knowledge of work published in India which has been referred to in standard treatises published in Europe and elsewhere. It is our best work that ought

to be offered to our own journals and publications and thus enable them to win adequate recognition.

I have one more duty to perform and that is to announce to you the decision of the managing committee to make the first award of the medal to Prof. Sudhansukumar Banerji for his work in the region of Mathematical Physics. Prof. Banerjee is well known to you and it has been my privilege on several occasions in this hall to refer to the quality of his work. I am glad that my high opinion of his work has been reinforced by the verdict of two of the most eminent men of science in this country who are both Fellows of the Royal Society and possess a world-wide reputation. These gentlemen were appointed by the Calcutta University to examine Professor Banerjee's researches and they did not take long to express their opinion on the merits of his work. I feel sure that the award to Professor Banerji sets up a high standard of achievement, which the future aspirants for the medal will not find it easy to surpass.

The following Prizes and medals were then distributed :—

(1) **Woodburn Research Medal**
Prof. T. K. Chinmayanandam, M.A., (Hons.)

(2) **Dr. Mahendra Lal Sircar Research Medal**
Dr. Sudhansukumar Banerjee, D.Sc.

In awarding Dr. Mahendra Lal Sircar Research medal, the Chairman said :—

Gentlemen, let me do the most pleasant duty of awarding the medal to its worthy receipient. The medal is a substantial one in more senses than one. Its physical substantiality lies in its being a medal of gold, weighing 15 or 20 *tolas*. And its moral substantiality consists in its being sanctified by the name of Dr. Mahendra Lal

Sircar, a name most dear to science in this country. It is sanctified no less by the name of the pious donor of the medal, Dr. Amrita Lal Sircar. And its importance is enhanced by the fact that the merits of the first receipient have been borne testimony to by one of our greatest scientific scholars Prof. Raman, aud by other distinguished scientists also, as we learn from him, who have confirmed his verdict, on merits of Mr. Banerjee's work.

(3) ANNUAL PRIZES AND MEDALS.

Physics and Chemistry.

In order of Merit.

Joykissen Mukherjee Gold Medal

1. Babu Manic Lal Das.

Temple Silver Medal

2. „ Profulla Chandra Nandi.

Jatindra Chandra Prize

3. „ Bankim Chandra Roy.

Botany.

Session 1917-18.

In order of Merit.

II YEAR.

1. Babu Suprakash Sen Gupta.
2. „ Nagendra Nath Sen.
3. „ Pulin Behary Ghose.

I YEAR.

1. Babu Sudhir Kumar Chakravarty.
2. „ Sashadar Goswami.
3. „ Sri Ranjan.

Presidential address.

Gentlemen,

This finishes the work of the day. It is customary on occasions like this for the occupant of the Chair to say

a few words before bringing the Proceedings of the meeting to a close. I think I have already said almost all that I wished to say, and what I am going to say now will be only a short resume of that.

The first thing that occurs to one in my position at to-day's meeting is a feeling of regret that our venerable President, Raja Peary Mohun Mookerjee has been prevented by ill health from being present here. But we have some consolation in the fact that he has permitted us to propose his name for re-election as our President for the next session, and we have the pleasure of having his honoured name still standing on our records as the President of this Association. He is not only a highly respected member of the enlightended landed aristrocacy of Bengal, but he has always been ready to associate himself with every good work meant for the amelioration of his country. He is moreover, the first Master of Arts in Science of the Calcutta University, and its oldest graduate now living.

The next thought that strikes me is that we have to congratulate the Science Association on the election of the three distinguished new members to whom I accord a most hearty welcome.

The next matter which calls for a reference from the Chair is the announcement of the first award of the Dr. Mahendra Lal Sircar Research Gold Medal. The research Gold medal, as I have already said, is not necessary to stimulate the workers in the field of science. They work for their own sake and for the sake of science. The institution of this research gold medal associated with the honoured name of Dr. Mahendra Lal Sircar, is a matter for congratulation to members of this Association, as being a most worthy act of their most worthy colleague, the Honorary Secretary, which will show to

the public a due appreciation of the cultivation of Science. Dr. Mahendra Lal Sircar founded the Association giving it the just and proper name "Association for the Cultivation of Science." Science has to be cultivated. Cultivators carry on their work, but the harvest, even where it is annual, is separated by an interval of a year or a full season between the time of sowing and the time of reaping, and when the harvest is not annual but perennial, as is the harvest to be reaped in the field of science, the interval of time for which the cultivator has to wait, is pretty long. This is the spirit in which, I am sure, the receipient of the first medal has done his work and those who will receive it in future will do theirs. Then again, it is matter for congratulation that the award of this medal has been for research work of a high order. I am glad to find that men of science like Prof. Raman and his unnamed compeers who are never lavish in their award of praise, speak highly of the work of Prof. Banerjee. Research is being honoured by these medals more than the students of science to whom we have the pleasure to award them.

I congratulate the Association and those who have been working in its interest, and also the prize-winners. And I would encourage those who have not been able to win prizes at the last examination by asking them to remember that prizes are no monopoly of any one. There is free competition, and no favourtism. Work and you will have your reward (cheers).

In proposing a vote of thanks to the Chairman Rai Bahadur Dr Chunilal Bose said :—

I rise to propose a vote of thanks to the Chair. I am not going to detain you long, but it is our paramount duty, before we leave this hall, to offer our heart-felt and greatful thanks to the venerable gentleman who

has occupied the chair at this meeting. Sir Gooroo Dass Banerjee is one of the oldest members of this Association and is one of its true and devoted friends. There is much to learn from the sweet and weighty speech that he has delivered from the chair this evening. It is surprising that at his age and in the indifferent state of his health, he could devote so much time and energy to the work of this Association. I have seldom found him missing any meeting of this Association, whether it be of the Executive Committee or of the General Committee, or any of its Scientific meetings. His presence is a source of inspiration to us and we can hardly repay the love and affection he bears for the workers of this Association. I ask you, Gentlemen, to join me in accord ing a hearty vote of thanks to the Chair.

In seconding the proposal for a vote of thanks to the Chair Mr. Raman said :—

I consider it a privilege to associate myself with the vote of thanks to the chair moved by my friend Dr. Chunilal Bose. The presence of Sir Gooroo Dass Banerjee at our meetings has been to us a source of strength and inspiration and the thanks which I have much pleasure in seconding are heart-felt and not merely a verbal expression.

SCIENCE CONVENTION.

Presidential address.

BY

SIR ASUTOSH MUKHERJEE, KT., C.S.I., M.A., D.L., D.SC. &c.

GENTLEMEN,

I have no desire in opening this Convention to interpose myself between Professor Raman and the audience who, like myself, must be anxiously waiting for what is sure to be a most illuminating lecture on the progress of Physical Science in Bengal in recent times. I desire, however, to point out that this Convention stands, in one respect at least, on a different footing from all the conventions which have preceeded it or those which are likely to follow. We had on no previous occasion and we are not likely to have on any future occasion, among our audience such distinguished scholars as Dr. Sadler, Vice-Chanceller of the University of Leeds, Dr. Gregory, Professor of Geology in the University of Glasgow and Mr. Hartog, Academic Registrar of the University of London and I call upon you to extend to them a most cordial welcome. I may also dwell on the significant fact that on the present occasion so many devoted students of Science have combined together with a determination to make our convention a decided success. I do not know what happens in other countries; but here at any rate, I have found that there is a temptation among our countrymen to dissipate their energy in different organization established from the point of view of personal gratification. I feel

convinced, however, that we must concentrate all our resources in order to make scientific researches successful in this country and I can very well imagine how the scene we are witnessing this evening would have deeply gratified our illustrious founder the late Dr. Mahendra Lal Sircar, the pioneer of scientific studies in this country. He is the spiritual father of every one of us however eminent, whose aspiration lies in that direction (applause).

TRANSACTIONS

Physico-Mathematical Section.

President of the Section:—C. V. RAMAN, ESQ., M.A.,
Sir Taraknath Palit Professor of Physics in the Calcutta University.

The PRESIDENT delivered the following address:—

On the Progress of Physical Science in Bengal.

The ten years from July, 1907 to June, 1917 which preceded my joining the University of Calcutta as Palit Professor of Physics afforded me numerous opportunities for studying, as an impartial and disinterested observer, the efforts made during the period in this University towards fostering higher studies and research in Physics. Looking back over these ten years, one cannot fail to be struck with the genuine progress that has been achieved, and with the fact that, to-day, the Calcutta University can claim to possess a real School of Physics, the like of which certainly does not exist in any other Indian University, and which, even now, will not compare very unfavourably with those existing in European and American Universities. What has impressed me most is the rapidity of the progress, the position now being very different from what it was ten years ago, and this is obviously a most hopeful sign for the future.

I propose in this address briefly to set out what seem to me to have been the principal features of the activities that have marked the past ten years. I may frankly state at once that a decade ago there was at

Calcutta a total lack of any thing that could claim to be regarded as a real centre of teaching and research in Physics. No doubt, the subject figured in the curricula of the University, but the higher teaching had latterly been very weak, particularly as regards Mathematical Physics, and research was absolutely at a stand-still. A new impetus was obviously required and it was not long in coming.

The Indian Association for the Cultivation of Science.

The first signs of healthy activity appeared in a purely indigenous institution, the Indian Association for the Cultivation of Science, founded many years ago by one of the most far-seeing Indians of the past generation, Dr. Mahendra Lal Sircar, who, in some measure, had succeeded in communicating to others his profound belief in the necessity for giving Indians opportunities for engaging whole time in the highest type of scientific work. By strenuous work Dr. Sircar had succeeded in getting together by private subscription just enough money to put up a building for the institution and ensure its permanence. Amongst those who were most closely associated with the work of this institution and took a deep interest in its welfare I should mention particularly the Hon'ble Sir Asutosh Mookerjee, who for some years, in an honorary capacity, delivered courses of lectures on Mathematical Physics and Higher Analysis at the Association. Unfortunately, however, Dr. Sircar's great efforts did not meet with all the success they merited, mainly because his appeals (repeated year

after year until his death in 1904) for funds with which to endow research scholarships and professorships failed to elicit any appreciable response. It is not surprising, therefore, that for many years things were at a stand-still.

My own work at Calcutta commenced in 1907 and was made possible by the special facilities put at my disposal by the present Honorary Secretary, Dr. A. L. Sircar, who had the Laboratory kept open at very unusual hours in order that I might carry on research in the intervals of my duties as an officer of the Indian Finance Department. Gradually others were drawn in to take part in the revived activities of the Association. The success which has attended these efforts is indicated by the fact that during these ten years the Association has issued as its own publications, fourteen special Bulletins, and three volumes of Proceedings, besides regularly publishing its Annual Reports. These publications have been warmly received abroad, and the Association is now in exchange relations with about fifty learned societies and institutions in various parts of the world. Its publications have been reviewed at length in current scientific literature and quoted by foreign scientific workers in original papers and standard text books. Some idea of the reputation to which the Association has attained may be obtained from the special editorial article regarding it that appeared in "Nature" of the 3rd of May, 1917, which is reprinted as *appendix A* of this address.

The New Regulations of 1909.

The introduction of the New Regulations, which came into force in the Calcutta University in 1909, undoubtedly laid the foundation for much of the subsequent progress. These regulations greatly strenhened Mathematical teaching in the University, and the study of Physics was considerably stiffened by the greater insistence upon laboratory equipment and practical work. The standard of the B.Sc, and M.Sc. Examinations was raised very considerably, and in fact the outlook as regards science teaching was completely altered for the better.

Among the activities of the time should be mentioned the Readership lectures delivered under the auspices of tee University by distinguished scientific workers, amongst whom may be principally mentioned Dr. A. Schuster and Dr. G. T. Walker. These lectures undoubtedly stimulated interest in the study of Physics, and brought home to the younger generation of the Uuniversity students the fact that scientific knowledge is essentially a product of the human mind and not simply some thing to be found printed in books. Opportunity was also given to local men to show their capacity. I may refer here to the lectures on "Optical Theories" delivered by Dr. D. N. Mallik, which have since been published in book form by the Cambridge University Press and have been favourably reviewed in "Nature" (October 4, 1917).

University College of Science.

Following after this, the most significant and important steps in advance achieved were the foundation of the Sir Taraknath Palit and Sir Rashbehary

Ghose Chairs* with their attached scholarships, and the establishment of the University College of Science. These made it possible for the first time to provide for the adequate teaching of the different branches of Physics and the creation of a school of research in Physics. The successful fruition of the object of the donors was, however, delayed and hampered by a combination of unfortunate circumstances. The most serious cause of delay was the absence of that support from Government which alone would have made possible the speedy construction and equipment of a first-class physical laboratory for research. Such assistance could surely have been looked for in view of the fact that the University had succeeded in securing by its own efforts a sum of about 25 lakhs from private donations as a nucleus for the establishment of the College of Science, and it was naturally a most grievous disappointment to find that such support was not forthcoming Further causes of delay were the law-suit on the Palit estate which made the permanency of the endowment a matter for the decision of the law courts, and the attitude of the Member for Education (Sir Harcourt Butler), who decline to permit my joining the Palit Chair until I completely resigned my

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* The duties of the Palit Professor are the following :—

(1) To devote himself to original research in his subject with a view to extend the bounds of knowledge. (2) To stimulate and guide research by advanced students in his special subject and generally to assist such students in Post-graduate study and research. (3) To superintend the formation and maintenance of the laboratory of the College of Science in his subject. According to the special terms of his appointment, the Palit Professor of Physics is under no obligation to take any share in the teaching of M. A. and M.Sc. Classes.

permanent appointment under Government in the face of this uncertainty. In fact, it was not until July, 1917, that it was possible for me formally to commence my duties in the University. The Rashbehary Ghose Professor is still detained in Germany where he was deputed for training prior to the War. Owing to the absence of the State aid which would have made the complete equipment of the College possible, and the subsequent difficulty in obtaining apparatus in consequence of the War, the formation of the Physical Laboratory was seriously hampered. In the face, however, of these serious difficulties, we have succeeded in carrying on experimental research and providing for the development of Post-graduate teaching.

Improvement of M.Sc. Teaching.

The establishment of the University College of Science has made possible a great advance in the higher teaching of Physics in the University. Prior to it, the only institution at Calcutta that was equipped (even in part) for M.Sc. work in Physics was the Presidency College. This institution, however, had arrangements only for higher teaching in Electricity, Magnetism, and Optics and ignored all the other branches of Physics, namely, Heat and Thermodynamics, Elasticity, Acoustics, and General Physics. Even in regard to Electricity, Magnetism and Optics, the arrangements formerly possible were most inadequate. Practically the whole of that part of Optics which has a practical application, namely, the higher theory of Optical instruments and photometry, was completely ignored, and as regards the other parts of Optics, no attempt appears to have been made to teach

the mathematical theory in a really adequate manner. With regard to Electricity and Magnetism, no serious attempt was made to teach those parts of the theory that have a close bearing on technical applications of the subject. These deficiencies were in great measure due to paucity of staff and equipment, and it is precisely here that the University College of Science has come in to fill the gap. Under the new arrangements, the higher teaching of Physics has been divided up between the combined staffs of the University College of Science and the Presidency College, and the resulting substantial addition to the number of men engaged on the work, and the high qulifications of the men attached to the University College have made a greater degree of specialization and a wider choice of subjects possible.

One respect in which the most substantial advance has been effected is in the teaching of the mathematical aspects of the different branches of Physics. This is now possible, because three out of the eight lecturers in Physics attached to the University College of Science are men who are first class M.Sc.'s in Applied Mathematics, and have since made a special study of Physics. Provision has also been made for teaching the different branches of Physics fomerly ignored, special attention being now paid to those that have the closest connection with technological practice. I have given in appendix B a list of the lecturers attached to the University College showing their academical qualifications. It will be seen that every one of these men has had the highest or nearly the highest University distinctions in his subject and year, and that several

of these men have distinguished themselves by success in research. It must be obvious to every unprejudiced inquirer that the teaching of Physics conducted by men of such stamp cannot possibly be much inferior to the best obtainable in any country. I would invite reference to the lists of the courses of lectures in Physics and the syllabuses prepared by the lecturers in different subjects. These have been printed by the University for circulation amongst the students, and a close scrutiny of the syllabuses will most clearly confirm and emphasise the facts referred to above.

Research Work.

As might have been expected, the foundations of the Palit and Rashbehary Ghose Chairs of Physics and of the attached scholarships has also led to a great expansion of original research in Calcutta. In fact, it may now be fairly claimed that the research papers published by myself and the researchers working in my laboratory cover important ground, and that an organisation for original research of a high type in Physics has been firmly established in the Calcutta University. In support of this statement, I give in appendix C a list of ***twenty five papers*** contributed by this school ***during the last three years***, most of which have been published or have been accepted for publication in the best known and most widely circulated scientific journals in the English language, namely, the "*L. E. and D.* Philosophical Magazine," "Nature" and the "Physical Review." I have also added summaries of some of these papers to enable their importance to be appreciated. The list contained

in Appendix C is very far indeed from completely representing all the work that has been turned out at my laboratory during the period considered, as I have not mentioned in it an extensive monograph on the Acoustics of Musical Instruments of the Violin Family extending to about 200 pages in print, (with thirty full-page photographic plates and a very large number of drawings) that represents a part of the original work which has been carried on by me personally during the past three years in the intervals of other duties. This monograph will shortly be issued by the Indian Association for the Cultivation of Scienc. Other investigations not mentioned in Appendix C are also in progress in my laboratory. In Appendix D, I give a list of five physical papers published by oher members of the Calcutta University staff in this period.

The most encouraging sign about the School of Physics at Calcutta is the extent to which the men who take part in Post-graduate teaching actively interest themselves in research work, and this feature would have been more marked but for the fact that the physical laboratory of the University College is still in its formative stage, and some of the best men in it have their hands full with the administrative detail of laboratory organization. Four out of the eight lecturers in Physics attached to the University College, namely Mr. S. K. Banerjee, Mr. S. K. Mitra, Mr. M. N. Shaha, and Mr. S. N. Basu, have succeeded in publishing research papers in European Journals, and two of the others have investigation in progress which are likely to prove fruitful in the near

future. Mr. S. K. Banerjee has in particular distinguished himself by his exemplary character and by his remarkable capacity in the fields of mathematical and experimental research. In the course of about three years, he has already published six original papers, and two more practically ready for publication. In recognition of his work, he has been awarded the Premchand Roychand Scholarship which of late years has grown to be one of the highest distinctions open to an alumnus of the Calcutta University. Mr. Banerjee's papers have attracted attention in Europe, and among those who have expressed their interest may be mentioned Prof. E. H Barton, F.R.S. and Prof. J. H. Vincent, both of whom are well-known for ther original investigations. Prof. Vincent wrote an account of Mr. Banerjee's work specially for the Journal "Knowledge," and Prof. Barton in reviewing Mr. Banerjee's work in "Science Abstracts" suggested that the instrument devised by him and used in his work should be given the name of "Ballistic Phonometer." I venture to think that in Mr. S. K. Banerjee, the Calcutta University possesses a man who can claim to to be regarded as a rising young researcher of the best type. Messrs. S. K. Mitra and N. Basu have also shown most praiseworthy ability and industry and are researchers of great promise.

I wish also to draw attention to the fact that appears from Appendices C and D, that a wide range of subjects is at present attracting the attention of the Calcutta School of Physicists. General Physics, Acoustics, Optics, Electromagnetic theory, Electric discharge, Spectroscopy, X-rays and Resonance Radia-

tion, and Radio-activity have all come in for a share of attention, and this wide range of interest will become even more manifest when our equipment is more complete, and I have had time to take on a large number of research workers and train them up. A more voluminous output may also be expected in the near future. Perhaps the most significant tributes to the fact that we have now a real scientific atmosphere at Calcutta are the numerous requests that I have received from teachers and scholars in various parts of India and Burma to be permitted to work in my laboratory and to carry on research. Such requests have been naturally complied with as far as possible, and I have now working in my laboratory an exceptionally capable young man from Madras, Mr. T. K. Chinmayanandam who was given a scholarship by the liberality of Kumar Sree Panchanan Mukhopadhya of Utterpara and who has already given signal proof of his originality by accomplished research (Appendix C). Others worked in my laboratory for short periods (during vacations and the like), but this is naturally a less satisfactory arrangement.

The Calcutta Physical Society.

In order further to stimulate research in Physics, and to afford Post-Graduate students the fullest opportunities to acquaint themselves with the original investigations in progress, it has been arranged to organize a special society with its head quarters at the University College of Science and devoted to the advancement of higher study and research in the subject. In response to an appeal issued over my signature, about eighty replies have been received

from teachers of Science and others living in various parts of India expressing their sympathy with the proposal, and agreeing to become foundation members of the Calcutta Physical Society. Among those who have responded to my appeal, I may mention the names of such distinguished savants as Dr. G. C. Simpson, F.R.S. and Mr. J. Evershed, M.A., F.R.S., both of the Indian Meteorological Department. The society will be soon inaugurated and there is every reason to believe that it will serve a most useful purpose.

Our Most Urgent Needs.

In the preceding paragraphs, I have set out in as brief a manner as possible the present state of affairs in regard to the higher study of Physics in the Calcutta University. I wish now to draw attention to a few of what I consider to be the most urgent needs of the Department of Physics in this University. First and foremost, I would put the necessity for further equipping the laboratories of the University College of Science so as to give the fullest possible scope for the development of the Calcutta School of Physics. We are doing all we can with the resources at our disposal, but if we are not to be left hopelessly behind in the great struggle for scientific progress that will arise when the War is over, it is necessary that we should begin now to prepare ourselves for it in every possible way. And I feel sure that any help that is afforded to us now will repay itself many-fold in due course of time. The second great need to which I wish to draw attention is the provision of residential accommodation in the premises of the University College of Science

for the Professors and staff engaged in research work. Such provision is in my opinion indispensible, if the best possible use is to be made of the time at the disposal of the workers. The third urgent need is the enlargement of the careers open to our workers. One way in which this could be achieved is that Government should show a sympathetic attitude towords our workers by recognising their proved merits and satisfying their just claims for admission into its educational and scientific services. To most men, the knowledge of the degree of recognition that awaits successful work is a stimulus not to be despised.

Appendix. A.

(Reprinted from "Nature" May 3, 1916.)

THE INDIAN ASSOCIATION FOR THE CULTIVATION OF SCIENCE.*

The genetic relation between the serious pursuit of natural science and the profession of medicine is nowhere better illustrated than in British India, and in British India nowhere better than by the Asiatic Society of Bengal (the original "Asiatick Society"), and by its autochthonous congener, the India Association for the Cultivation of Science, founded in 1876 by Dr. Mahendra Lal Sircar, a practioner of medicine in the Indian quarter of Calcutta.

At a time when Indian universities were the purely examining bodies so dear to the Philistine soul, when secondary education in India was mainly bookmongery (to call it "literary" would be a fault to heaven), and literary gentlemen were brought from England to feed raw Indian youths with husks of commentary laboriously ground from the English classics, Dr. Mahendra Lal Sircar, a medical man immersed in the anxieties of a private practice, was probably the only educated Indian in Bengal whose ideas of education were approximately those held generally to-day by men of science in Great Britain.

Dr. Sircar, being beyond his learning and accomplishments a man of great sagacity and urbanity, did not agitate or make a noise, but, with single-minded devotion to higher issues, he set a-going in a convenient part of his native town, and for many years carefully fostered, a society much of the style of the Companies of Friends of Natural History, the aim of which, to begin with, was, and had to be generally educative. This society

*Report of the Indian Association for the Cultivation of Science for the year 1914. (Calcutta, 1916.)

was appropriately called an association for the cultivation of science. By degrees, and by the accretion of laboratories for particular studies, the institution, while retaining an educational character, advanced to the differentiated technical stage; and now, beyond its educational purpose, it has become a well-organised and well-equipped institution for original experimental research.

The report for the year 1914, lately received, shows that in addition to the seven regular courses of lectures on different branches of science delivered to students, there emanated from the association ten original papers—four on physico-mathematical subjects, five chemical, and one biological.

Appendix B.

List of the Lecturers in Physics attached to the University College of Science.

Name of Lecturer.	Class in which he passed his M.A. or M.Sc. Examination.	Position in order of merit in his examination.	Subjects in which he is Lecturer.	Number of Research papers written by him.
Mr. P. N. Ghosh, M.A. (Calcutta) (Physics).	First	First	Geometrical Optics and Theory of Optical Instruments, Conduction and Convection of Heat.	
Mr. J. C. Mookerjee, M.A. (Calcutta)	"	"	Theory of Vibrations and Acoustics.	
Mr. S. K. Banerjee, M.Sc. (Calcutta) (Applied Math.)	"	Second	General Physics, Electromagnetic Waves, Infinitesimal Calculus and Differential Equations	Eight.
Mr. S. K. Mitra, M.Sc. (Calcutta) ..	"	First	Physical Optics and Spectroscopy	
Mr. S. K. Acharyya, M.Sc. (Calcutta)	"	Second	Magnetism and Applied Electricity and Theory of Heat.	Two.
Mr. S. N. Basu, M.Sc. (Calcutta) (Applied Math.)	"	First	Elasticity and Molecular Physics, Theory of Relativity.	
Mr. M. N. Shaha, M.Sc. (Calcutta) (Applied Math.)	"	Second	Thermodynamics and Quantum Theory.	Three.
Mr. A. Saha, M.Sc. (Calcutta) ...	"	First	Electromagnetism and X Rays.	

Appendix C.

List of *twenty-five* original papers contributed in the *three years* 1915, 1916, 1917, by the Palit Professor of Physics and the researchers working in his Laboratories.

I. On the maintenance of combinational vibrations by two simple Harmonic Forces, by C. V. Raman, M.A. (Physical Review, January, 1915, pages 1 to 20 with four full-page plates).

In this paper, the author has recorded the discovery of a new class of resonance phenomena exhibited by a *symmetrical* vibrating system under the simultaneous action of two periodic forces.*

II. On motion in a periodic field of force, by C. V. Raman, M.A. (Philosophical Magazine, January, 1915, pages 15 to 27 with two full-page plates).

In this paper the author has described a new type of vibratory motion set up by the action of a periodic force, the frequency of the vibration being a *submultiple* of that of the impressed field of force.

III. On intermittent vision, by C. V. Raman, M.A. (Philosophical Magazine, November, 1915, pages 701-2).

The following summary of this paper is taken from "Science Abstracts": [In a recent paper Mr. A. Mallock. F.R.S., brought forward the hypothesis that a slight mechanical shock to the head or body of the observer produces a periodic but rapidly extinguished paralysis of the perception of sight, and that the nerves on which seeing depends cannot bear more than a certain amount of mechanical acceleration without loss of sensibility.† Later, Prof. S. P. Thompson,† F.R.S. criticised

* This is looked for as a consequence of two previous investigations by the author, Phil. Mag. Oct. '12 and Physical Review, Dec. '12.

† A. Mallock, F.R.S., Proceedings of the Royal Society, Series A. Vol. 89, 1914. S. P. Thompson, F.R.S., ibid, Vol. 90.

Mallock's conclusions stating that Mallock's hypothesis is unnecessary and suggesting that retinal fatigue is the cause of the effect. The author of the present paper considers that Thompson's suggestion is also untenable, and brings forward the following explanation :—So long as the retina is absolutely at rest, and the white and dark sectors on the revolving disc follow one another at intervals short compared with the period of persistence of vision, the disc appears uniformly illuminated, but if the retina is set in motion even for a small fraction of a second, say by a slight mechanical shock or by the eye involuntarily following the motion of the sectors, and if the direction of this motion is such that the white sectors remain on any given portion of the retina for a longer interval than they otherwise would, the impression of light over the areas occupied by the dark sectors has time enough to die away appreciably, and we thus get the illusion of stationary white sectors on a dark ground. A movement of the retina in the opposite direction could however, produce little or no perceptible effect, provided the rotation of the disc is sufficiently rapid. This is exactly what is found in experiment.]

IV. On Discontinuous Wave-Motion, by C. V. Raman, M.A. & S. Appaswamier, (Philosophical Magazine, January, 1916. pages 47 to 52 with one plate).

For an excellent summary of this paper by Prof. E.H. Barton, F.R.S. see Science Abstracts, No, 352, 1916.

V. On the Wolf-Note in the Violin & Cello, by C. V. Raman. M.A. (Nature, pages 362 to 363, June, 1916, with one plate).

In this paper the author has described certain phenomena observed in the excitation of the violin or cello at the wolf-note pitch and has put forward a theory to account for these phenomena. Incidentally, he has criticised some earlier observations on the subject published in the Proceedings of the Cambridge Philosophical Society by Mr. G. W. White. In a subsequent issue of "Nature" (Sept. 1916), Prof. Tyndall of

Bristol University and Mr. G. W. White wrote a joint letter in which they admitted the correctness of the author's views and the justice of his criticisms.

VI. On Aerial Waves generated by impact, by S. K. Banerjee M.Sc. (Philosophical Magazine, July, 1916, pages 96 to 111).

The author has investigated in this paper both theoretically and experimentally the origin and the characteristics of the sound produced by impact. It has been shown by Hertz in his well-known paper on the collision of elastic solids* that when two bodies impinge on each other with moderate velocities, the elastic distortions are more or less entirely localised over the region of contact and that the duration of impact, though in itself a very small quantity, is a large multiple of the gravest period of free vibrations of either body. It follows therefore that no appreciable vibrations of the solids are set up by the impact. In a recent paper† Lord Rayleigh has investigated the circumstances of the first appearance of sensible vibrations in the case of two impinging spheres, and his results show that under ordinary conditions vibrations cannot be excited in a perceptible degree. Even if vibrations be excited at all, the pitch of the gravest sound so produced will be very high, almost beyond the range of audibility. To expain the production of the characteristic click when two billiard balls impinge on each other, the following hypothesis has been put forward by Mr. Banerjee in this paper. The whole of the sound of impact is practically due to the impulse given to the fluid medium by the surfaces of the spheres which undergo a sudden change of velocity as a result of impact. Mr. Benerjee's hypothesis regarding the origin of the sound has been confirmed by mathematical investigation and also experimentally with the help of a new type of apparatus in which the ballistic principle has been utilised. [Prof. Barton has suggested that this instrument

* Hertz's "Miscellaneous papers," English Ed., page 146. (See also Loves' Treatise on Elasticity, Second Ed., page 195).

† Lord Rayleigh, Phil. Mag., Vol. XI, pp. 283—291 (1906).

should be named a "Ballistic Phonometer"]. Mr. Banerjee has investigated the distribution of intensities of sound in different directions round the colliding spheres, and studied the manner on which the sound depends—(1) on the duration of impact, (2) on the coefficient of restitution, (3) on the diameters of the balls, and (4) on the relative velocity of impact. The distribution of intensity round the colliding spheres is very remarkable. It is maximum in the line of collision and it gradually decreases until it assumes practically a zero value on the surface of a cone of semi-vertical angle sixty-seven degrees and then it again increases until it assumes a second but feebler maximum in the plane perpendicular to the line of impact. The intensity of the sound has also been found to obey some very interesting laws depending on the changes of velocity and the diameters of the colliding spheres which have been verified experimentally by the use of the ballistic phonometer.

VII. On the Wolf-Note in Bowed Stringed Instruments, by C. V. Raman, M.A. (Philosophical Magazine, October, 1916, pages 391 to 395).

This is a further development of the author's first paper on the subject. In this paper the discovery is recorded of two new wolf-notes, that do not previously appear to have been noticed by violinists, and the discovery is also announced of the remarkable fact that under a very considerable variety of conditions, the vibrations of a bowed string are cyclical (not periodic).

VIII. On Discontinuous Wave-Motion, Part, II, by C. V. Raman, M.A. and Asutosh Dey (Philosophical Magazine, February, 1917, pages 203 to 207, with one plate).

In an important paper on the theory of discontinuous wave propagation, Harnack* has given an elegant general formula expressing the mode of vibration of a string whose configuration is completely determined by a finite number of discontinuous changes of velocity travelling over it. As an illustration of his

* A. Harnack, Mathematische Annalen, Vol. XXIX, p. 486.

result Harnack has discussed, in some detail, the cases in which the form of the vibration is determined by one and by two such changes of velocity respectively. The analysis indicates that the case of a single discontinuity is identical with that of the principal mode of vibration of a bowed string, and in a previous communication by one of the present authors, it has been shown how this mathematical result may be confirmed experimentally. The general case of two discontinuities considered by Harnack covers a considerable and interesting variety of forms of vibration, and the method described in the previous paper has now been successfully extended so as to obtain an experimental confirmation of Harnak's results in some of these cases also. In these experiments, the characteristic vibration forms produced by the motion of two unequal discontinuous changes of velocity of opposite signs have been observed and recorded photographically. Some are of the symmetrical type and the others are asymmetrical. The results are in full agreement with the mathematical theory first given by Harnack. The vibration curves are found to be intermediate in form between those characteristic of bowed and plucked strings. The paper includes a plate with seven reproductions of the photographic records of the vibrations.

IX. On Discontinuous Wave Motion, Part III, by C. V. Raman and Asutosh Dey. (Philosophical Magazine, April, 1917, pages 352 to 357 with plates).

This is a continuation of previous work on the same subject. See paper VIII above. In this paper the authors hava shown how the mode of vibration of a stretched string characterised by two discontinuous changes of velocity of the same sign can be produced experimentally. This type of vibration is of very special acoustical interest in relation to the theory of the periodic and cyclical excitation of bowed strings. The paper is illustrated by photographic records secured in the course of the work and contains a detailed theoretical discussion.

X. On the Diffraction Phenomena Observed in the Testing of Optical Surface, by S. K. Banerjee, M.Sc. (Nature, May 10th, 1917).

In the Philosophical Magazine, for February, 1917, Lord Rayleigh has published an investigation of the phenomena to be expected according to the wave theory when an optical surface is tested at the focal plane by the well-known method due to Foucault, and has shown that even when the whole of the light is cut off by an advancing edge in the focal plane, the edges of the aperture show a marked brilliancy which is symmetrical about the axis. An interesting question arises as the manner in which this effect would be modified if the light is screened not exactly in the focal plane but a little in front of or behind the focus. On testing this effect, it has been found by the author that the Rayleigh effect is still observed but that the two edges differ very markedly in their brilliancy, one of the edges becoming several times brighter than the other. Photometric comparisons of the brightness of the two edges have been made by using a rotating-sector photometer devised by C. V. Raman and costructed by Hilger, and the results are found to be in agreement with those found from a mathematical theory worked out by Mr. Banerjee.

XI. On the Maintenance of Vibrations by a Periodic Field of Force, by C. V. Raman, M.A. and Asutosh Dey. (Philosophical Magazine, August, 1917, pages 129 to 137 with one plate).

A very clear summary of this paper wilf be found in "Science Abstracts" for October, 1917.

XX. On the Alterations of Violin Tone Produced by a Mute, by C. V. Raman, M.A., (Nature, October 4, 1917).

In this communication, the author has given a mathematical theory of the action of a violin mute and has criticised the work of two Dutch Physicists, Mr. J. W. Giltay and Prof. De Haas on the motion of a bridge of a violin, published in the Proceedings of the Royal Society of Amsterdam for January 1910. The theory now put forward is based upon the author's observations on the pitch of the wolf note as altered by the mute, and leads to the very remarkable conclusion that over a

considerable range of pitch, the mute actually increases the amplitude of vibration of the body of instrument. This has been confirmed experimentally.

XIII. On Aerial Waves generated by Impact, Part II., by S. K. Banerjee-M.Sc., (This paper was communicated to the Philosophical Magazine and has been accepted for publication in that journal.)

The investigation of the origin and character of the sound due to the direct impact of two similar solid spheres which was described in the Phil. Mag. for July, 1916, has been extended in the present paper to the cases in which the impinging spheres are not both of the same diameter or material. The relative intensities of the sound in different directions have been measured by the aid of the ballistic phonometer, and have been plotted in polar co-ordinates. As might be expected, the curves thus drawn show marked asymmetry in respect of the plane perpendicular to the line of impact.

A detailed mathematical discussion of the nature of the results to be expected has been given by the author, and intensity curves similar to those found experimentally for the case of impact have been obtained. A further confirmation is thus obtained of the hypothesis regarding the origin of the sound suggested by the work of Hertz and of Lord Rayleigh on the theory of elastic impact.

When the impinging spheres, though not equal in size, are not of the same or nearly the same density, the intensity curve drawn for the plane of observation shows the sound to be a maximum along the line of impact and also in two other directions making equal acute angles with this line. The sound is a minimum along four directions in the plane. In practically all other cases, that is when the spheres differ considerably either in density alone, or both in diameter and density, the intensity is found to be a minimum along the line of impact in either direction, and to be a minimum along directions which are nearly but not quite perpendicular to the line of impact. The

form of the intensity curve is practically determined by the diameters and the masses of the spheres.

XIV. On the Diffraction of Light by Cylinders of Large Radius by M. N. Basu, M. Sc. (This paper was communicated to the Philosophical Magazine and has been accepted for publication in that Journal).

A well-known American Physicist, C. F. Brush, has recently published some interesting observations on the diffraction of light by the edge of a cylindrical obstacle*. The problem of the diffraction of electromagetic waves by a cylinder is one of great importance and has been investigated mathematically by many well-known physicists among whom may be mentioned J. J. Thomson†, Lord Rayleigh‡ and P. Debye§. The phenomena observed in the immediate neighbourhood of the cylinder however required further investigation. It was found that the views put forward by C. F. Brush to explain his observations were open to objection and presented serious difficulties.

The present work was undertaken by the author in order to find the true explanation of the effects and to develop a mathematical theory which would stand quantitative test in experiment. This has now been done, and in the course of the investigation various features of importance overlooked by Brush have come to light. The following are the principal conclusions arrived at: (*a*) The fringes seen in the plane at which the incident light grazes the cylinder are due to the simple interference of the direct and reflected rays, the position of the dark bands being given by the formula $x=\frac{3}{4}\cdot(2a)^{\frac{1}{3}}, (n\lambda)^{\frac{2}{3}}$; *(b)* the fringes in a plane further removed from the

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* "*Some Diffraction Phenomena; Superposed Fringes* by C. F. Brush, *Proceedings of the American Philosophical Society*, 1913, pages 276-282.

† "*Recent Researches in Electricity and Magnetism,*" p. 428.

‡ *Phil Mag.*, 1881. Scientific works, Vol. 1, p. 534.

§ P. Debye, "*On the Electromagnetic field surrounding a Cylinder and the theory of the Rainbow,*" *Phys. Zeitschr.* 9, pp. 775-778, Nov. 1808. Also, *Deutsch. Phys. Gesell. Verh.* 10. 20, pp. 741-749, Oct., 1908, and *Science Abstracts*, No. 158. 1909.

source of light than the cylinder are of the Fresnel class due to the edge grazed by the incident rays, but modified by interference with the light reflected from the surface behind the edge. The positions of the dark bands in these fringes are given by the formula* $x=2d\theta+3a\theta^2/2$, $n\lambda=2d\theta^2+2a\theta^3$, from which θ is to be eliminated; (*c*) when the focal plane of the observing microscope is on the side of the cylinder towards the light, the direct and the reflected rays do not both cover exactly the same part of the field, and by putting the focal plane sufficiently forward towards the light, they may be entirely separated. When this is the case, the fringes of the ordinary Fresnel type due to the edge of the cylinder may be observed, and inside the shadow we have also an entirely separate system of fringes due to the reflected rays, the first and principal maximum of which lies alongside the virtual caustic formed by oblique reflection; the distribution of intensity in this system can be found from the well-known integral due to Airy; (*d*) but when the focal plane is not sufficiently in front of the edge, the caustic and the reflecting surface are nearly in contact, and Airy's investigation of the intensity in the neighbourhood of a caustic requires modification. It is then found that only a finite number of bands (one, two, three or more according to the position of the plane of observation) are formed within the limits of the shadow and not an indefinitely large number as contemplated by Airy's theory. The rest of the fringes seen in the field are due to the interference of the direct and the reflected rays but modified to a certain extent by diffraction at the edge of the cylinder.

The paper is illustrated by interesting photographs of the diffraction phenomena described.

XV. On the Asymmetry of the Illumination Curves in Oblique Diffraction, by S. K. Mitra, M.Sc. (This paper was communicated to the Philosophical Magazine and has been accepted for publication in that Journal).

* This formula is subject to a small correction which is of importance only when d is large.

In a series of papers published in the Philosophical Magazine it has been shown by Mr. C. V. Raman that the phenomena of oblique diffraction by a rectangular aperture present some remarkable features which are not explained on the classical treatment of diffraction problems but require the more rigorous discussion on the basis of the electro-magnetic theory of light. In the present paper Mr. Mitra has extended the experimental work to the cases in which the diffracting aperture consists of two, or more reflecting surfaces. The general result is to confirm the results arrived at by Raman and to indicate the lines for further research on this problem. The paper is illustrated by very interesting photographs showing the diffraction phenomena in question.

XVI. On the Wolf Note in Bowed stringed instruments, by C. V. Raman, M.A. (Accepted for publication in the Philosophical Magazine).

This is a further instalment of tho author's researches on the subject. In it an account is given of some interesting results obtained with a mechanical violin player constructed and used in the author's laboratory.

XVII. On the Flow of Energy in the Electromagnetic Field surrounding a Perfectly Reflecting Cylinder, by T. K. Chinmayanandam, B.A. (Hons.)

In a recent paper,* Mr. N. M. Basu has discussed the general features of the phenomena observed in the immediate neighbourhood of a perfectly reflecting cylinder, on which plane light waves are incident in a direction at right angles to its axis. Further investigation was, however, necessary in order to establish the formulæ for the distribution of light intensity in the various parts of field. These formulæ have now been obtained by Mr. Chinmayanandam and subjected to a detailed experimental test. Besides describing the results of a photo-

* Phil. Mag., November 1908, January 1909, and May 1911.

* N. M. Basu—*On the Diffraction of Light by Cylinders of Large Radius*, (see paper No. XIV in this Appendix).

metric study that has been carried out, the present paper also considers the form of the lines of flow of energy through the field from the stand point of electromagnetic theory with reference to the work of Profs. R. W. Wood* and Max Mason‡ on the simpler case of the interference field due to two point sources of light.

Using a method suggested by Debye's investsgation quoted above, Mr. Chinmayanandam has obtained the following results :—

(a) The positions of the maxima of illumination are determined by eliminating θ from the pair of equations,

$$2y\theta + 3a\theta^2/2 = x\,;\; 2\theta^2(y + a\theta) = m\lambda/2$$

or from the pair of equations

$$2y\theta + 3a\theta^2/2 = x\,;\; 2\theta^2(y + a\theta) = m\lambda/2 - \epsilon\lambda/2\pi$$

according as the plane of observation is in front of the cylindrical 'edge" or behind it. x, y are the co-ordinates of any point, the origin being the "edge" of the cylinder. ϵ is a small angle which for large values of y becomes equal to $\pi/4$.

(b) The visibility of the fringes varies in an interesting manner with the position of the part of the field under observation. It is practically constant over the entire plane of observation when this coincides with the plane passing through the "edge" but falls off when it it moved further away from the source of light, the decrease being greatest for the regions furthest from the surface. When the part of the field under observation is between the "edge" and the source of light, the visibility of the fringes reaches the maximum value at the surface of the cylinder, falling off slowly as we recede from it.

(c) The loci of maxima and minima of illumination are given by $r\theta^2 = m\lambda/4$ and the "mean lines of flow" of energy are given by $r\theta = \text{const.}$ and are for small values of θ less inclined to the direction of the incident rays than the former set of curves.

* Prof. R. W. Wood, F.R.S., Philosophical Magazine, 18, page 250.

† Prof. Max. Mason, Phil. Mag., 29, page 290.

The actual lines of flow crinkle about these mean lines; the "wave-length" of the crinkles increases as we move along the direction of the incident rays, and decreases as we move in a direction at right angles to it, away from the cylinder. The "amplitude" of the crinkles decreases as r and θ increase, and vanishes at sufficiently large distances from the cylinder.

The paper is illustrated by numerous diagrams and photographs, and contains detailed tables of experimental data which are found to be in agreement with theory.

XVIII. Resonance Radiation and the Quantum Theory, By T. K. Chinmayanandam, B.A. (Hons.)

In a recent paper* in the Philosophical Magazine, an attempt has been made by Dr. Silberstein, to explain the phenomena of Resonance Radiation on the principles of classical mechanics. Dr. Silberstein considers that the electron which emits the radiation is a non-Hookean resonator *i.e.*, a system in which the restitutive force is not simply proportional to the displacement, the case being analogous to that of combinational tones in sound. Dr. Silberstein finds the consequence of this assumption to be, that the Resonance series should be characterized by constant frequency intervals. He gives in his paper a table, prepared from Wood's data, and thinks that his conclusions from the theory are supported by facts. But a critical examination of his own figures shows that the frequency intervals have a most decided tendency to decrease on the long wave-length side. Adopting a method of calculation, in which the effect of experimental errors is better minimised, Mr. Chinmayanandam has prepared a table from Wood's data† for the frequencies of the components of the Resonance series of Iodine vapour, and finds that it is not the frequencies themselves, but their square roots, that have constant intervals in this series.

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* Dr. Silberstein on *Fluorescent vapours and their magneto-optic properties*, Phil, Mag., Sept. 1916.

† Wood, Phil. Mag. 14, p. 684.

Mr. Chinmayanandam then proceeds to apply the theories of Atomic structure developed by Bohr and others* to the explanation of the phenomena of Resonance Radiation and shows that, in general, the frequency intervals in the Resonance-series cannot be constant as supposed by Dr. Silberstein. The relations deduced by Mr. Chinmayanandam are in general accordance with the experimental facts observed by Wood.

Mr. Chinmayanandam then proceeds to consider the theory of characteristic X-Rays and Corpuscular radiations and shows how the recent results obtained by Ishiwara† and by Barkla and Shearer‡ may be explained.

XIX. On the Theory of the Foucalt Test and the Radiation from the Edges of Diffracting Apertures, by S. K. Banerjee, M.Sc.,

In this paper, Mr. Banerjee extends the method of investigation suggested in a recent paper by Lord Rayleigh§ to various cases of interest not considered by him. In particular, the theory is given of the luminosity observed at the boundary of the circular aperture of a lens in the Foucalt test. Mr. Benerjee has found that the configuration of the luminous fringes observed at the boundary in these and analogous cases presents some features which do not appear to have been observed or described before. The most remarkable of these is that the boundary itself appears non-luminous when observed solely by diffracted light, but is surrounded by luminous bands on either side, the position and intensity of which is ascertainable by mathematical treatment. The extreme rapidity with which the luminosity falls to zero at the boundary is noteworthy. These phenomena have an important bearing on the general theory of diffraction, being analogous to the Gouy-

* Dr. N. Bohr, Philosophical Magazine, 1913.

† Jun Ishiwara, Proc. of the Tkyo Math. Phys. Soc., Ser. 2 Vol. 9, p. 160. (July, 1917).

‡ Barkla and Shearer, "On the Velocity of electrons expelled by X-rays," Phil. Mag., Dec. 1915.

§ Lord Rayleigh, Phil. Mag. Feb. 1917. "On methods for detecting Optical Retardations, and the Theory of the Foucalt Test,"

Sommerfeld effect of the emission of light by a diffracting edge*, and have been studied by Mr. Banerjee for various forms of aperture. Some new colour-phenomena in the Foucault test due to diffraction have also come to light. A detailed mathematical treatment is given and the experimental data are found to be in close agreement with the results deduced. Numerous photographs and diagrams illustrate the paper.

XX. On the Diffraction of Light by an Obliquely-held Cylinder, by Mr. T. K. Chinmayanandam, B.A. (Hons.)

In this paper, Chinmayanandam considers the the theory of the diffraction pattern formed by a transparent cylinder obliquely-held in the path of plane waves of light. The case is found to present features of considerable interest which do not appear to have been previously noticed, though the case of a cylinder held parallel to the plane of the incident waves has been discussed by various writers. The remarkable features are those noticed at and near the incidence at which the caustics formed by internal reflection from the cylinder coincide and vanish. Photographs of the diffraction-pattern have been secured and will be published with the paper.

XXI. Sommerfeld's treatment of the Diffraction Problem, by S. K. Mitra, M.Sc.

In a famous paper‡, Sommerfeld has given a rigorous treatment on the basis of the electro-magnetic equations, of the theory of diffraction by a semi-infinite perfectly reflecting screen. His integrals when simplified given an expression which for moderate incidences and for small angles of diffraction is partically the same as that obtained from the ordinary Huyghens-Fresnel treament of diffraction-phenomena. For large angles of diffraction, there is a divergence between the two sets of

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* Gouy, Ann. d. Phys. et. de. Chim., (6), 8, p. 145, (1886).
Sommerfeld, Math. Ann., Vol. XLVII, p. 317, (1895).

† For references see those quoted under paper XIV. Also recent papers by Mobius on the Rainbow in the Annalen Der Physik.

‡ Math. Annalen, 1895.

results and this has already been pointed out by various writers. It does not however appear to have been pointed out by anyone that, *for very oblique incidences*, there is a divergence between the results given by the Sommerfeld treatment and these found from the ordinary theory even for small angles of diffraction. This has now been done by Mr. Mitra. On testing the indications of Sommerfeld's formula experimentally for verp oblique incidences, it is found that the former are valid only for light polarised in the plane of incidence, and not for light polarised at right angles to the plane of incidence. This appears to be the case because the boundary conditions assumed by Sommerfeld are not satisfied in practice for a screen of any known substance.

XXII. On Oscillations of Sub-Harmonic Frequencies in a Field of Force, by Ashutosh Dey.

In continuation of previous investigations on the subject of periodic motion in a field of force, Mr. Dey has found that an arrangement originally suggested by Lord Rayleigh* for the maintenance of vibrations by forces of double frequency, also exhibits resonance when the frequency of the oscillation is any sub-multiple of the frequency of the impressed force. The importance of this observation is that the dynamical system in this case has a free period of its own in the absence of the impressed periodic field, and thus determines the frequency of its own excitation.

XXIII. On Maxwell's Stresses. by M. N. Shaha, M.Sc. (Phil. Mag. March 1917.)

XXIV. On the Limit of Interference in the Febry-Perol Interferometer, by M. N. Saha. (This will appear in the Physical Review.)

XXV. On the influence of the Finite Volume of Molecules on the Equation of State, by M. N. Saha M.Sc. and S. N. Basu, M.Sc. (This will appear in the Phil. Mag.)

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* Lord Rayleigh, Scientific Papers, Vol. II.

APPENDIX D.

List of five physical papers published by other members of the University staff in the years 1915-17.

(1) Theory of Dispersion by D. N. Mallik, D.Sc., F.R.S.E., Phil. Mag., Ppril, 1915.

(2) Electric Discharge in a Transverse Magnetic Field by D. N. Mallik and A. B. Das, Phil Mag., July, 1916.

(3) High vacuum Spectra of Gases by D. N. Mallik and A. B. Das, Phil. Mag., March, 1917.

(4) On Absorbtion Spectra, by D. B. Meek, M.A., B.Sc. (Trans. of the Chmical Society, 1917.)

(5) On the Ionisation tracks of Hydrogen particles produced by the collision of *a* particles with Hydrogen Atoms, by D. Bose, Phys. Zeit., August, 1916.

Experiments with mechanically played violins (illustrated)—
by Prof. C. V. Raman, M.A.
(See Bulletin No. 15).

On Resonance Radiation and the Quantum Theory—
by T. K. Chinmayanandum, B.A.
(See Proceedings, vol. III, Pt. 6).

On the Theory of Foucault's Test and the Radiation from the Edges of Diffracting Apertures.[1]

By

Sudhansukumar Banerji, M.Sc.,

Assistant Professor of Applied Mathematics, Calcutta University;
Life Member, Indian Association for the Cultivation of Science.

§ 1. *Introduction.*

In a recent paper published in the Philosophical Magazine[2], Lord Rayleigh has given a treatment on the principles of the wave theory of the phenomena observed when an optical surface is examined by the well-known 'knife-edge' test due to Foucault in which a screen is placed in the focal plane and advanced gradually so as to cut off the rays coming to a focus, the optical imperfections, if any, becoming evident when the surface is viewed by the eye (or through a telescope) placed behind the focal plane. Assuming that the surface is bounded by parallel straight edges, and that the source of light is also linear, Lord Rayleigh has shown how the luminosity of the boundaries which is observed when the bulk of the light is cut off, may be accounted for as due to the diffraction of the rays reaching the focal plane. He has also considered the effects produced by introducing optical retarda-

1. A preliminary note describing the results contained in Section 5 of this paper was published in 'Nature', May 10, 1917.

2. Lord Rayleigh, "On Methods for detecting small Optical Retardations, and on the Theory of Foucault's Test", Phil. Mag., Feb., 1917.

tions of a linear type over the surface of the aperture. In the present paper, I have extended Lord Rayleigh's method of investigation to other cases of interest, particularly those in which the surface under test has a circular boundary and is illuminated by a point source of light. (This, it may be remarked, is the case that most frequently occurs in practice[3]). In the course of the work, it was found that the configuration of the luminous fringes observed at the boundary of the surface presents some very remarkable features which will also be dealt with in this paper. To illustrate the results obtained, photographic records have been secured, a selection from which is reproduced in the Plate. These phenomena have an important bearing on the general theory of diffraction, being evidently related to the well-known Gouy-Sommerfeld effect of the emission of light by a diffracting edge[4]. I have also attempted to consider the effects noticed in Foucault's test, when the retardations are of a non-linear type, that is when the foci of the pencils do not all lie in the plane of the knife-edge. In the practical applications of Foucault's test, these are probably more common than retardations of the linear type.

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3. See the Memoirs by Draper and Ritchey on the Construction of a Silvered Glass Telescope, Smithsonian Contributions to Knowledge, Vol. XXXIV (1904).

4. Gouy, Ann. d. Phys. et de Chim., (6), 8, p. 145, (1886). Sommerfeld, Math. Ann., Vol. XLVII, p. 317, (1896). See also, E. Maey, Wiedemann's Annalen, 49, (1893), and Kalaschnikow, Journ. Russ. Phys. Ges., 44 (1912). For a rigourous treatment of the problem of diffraction of light by a rectilinear slit, see Schwarzschild, Math. Ann., Vol. 55, (1902).

§ 2. *Case of the Circular Boundary.*

As remarked above, the optical surfaces examined by the 'knife-edge' test are most frequently limited by a circular aperture, the illumination being that due to a point source. Fig. 9 (Plate) reproduces a photograph of the luminosity observed at the boundary when the knife-edge is put in horizontally into the focal plane from below so as to cut off most of the light. It will be noticed that the luminosity is a maximum on the upper and the lower boundaries, and diminishes to zero at the ends of a horizontal diameter. In order to give definiteness to a discussion of this effect, it is necessary to postulate some specified form for the boundaries of the aperture in the focal plane which admits the diffracted rays into the field of view of the observing telescope. For instance, we may assume that a horizontal slit is placed in the focal plane below the centre of the field. Fig. 12 in the Plate reproduces the beautiful lunette-shaped diffraction fringes that appear on either side of the boundary of the circular aperture with this arrangement. The luminosity, as in the case of the simple knife-edge test, tends to zero at the ends of a horizontal diameter. The explanation of this fact and of the peculiar form of the fringes will appear later.

More striking still are the interference phenomena obtained when the boundary is observed through a pair of apertures of the same form placed in the focal plane. With two horizontal slits placed *on the same side* of the centre of the field, lunette-shaped *interference* fringes are observed, the central fringe which coincides with the boundary being white (fig. 15 in

the Plate). But when two horizontal slits are placed *on opposite sides* of the centre of the field, the *central fringe is black*, in other words, the boundary of the aperture is itself non-luminous but appears surrounded on either side by luminous bands (fig. 6 in the Plate). This remarkable fact is one of great generality. In all cases in which the apertures in the focal plane through which the diffracted rays pass (whatever be their actual form) are symmetrically disposed about the centre of the field, the latter itself being excluded, the image of the boundary of the diffracting surface appears as a black line. This is irrespective of the actual form of the boundary itself, that is, whether it is circular or of any other shape whatsoever. Fig. 16 in the Plate represents the appearance of the circular boundary when a horizontal wire is placed across the centre of the focal plane. A fine black line may be seen running through the luminous arcs and dividing them into two. A case that admits of detailed mathematical treatment is that in which the arrangement is completely symmetrical about the axis. Figs. 7 and 10 in the Plate show the results obtained when the central part of the field at the focal plane is blocked out by a circular disk and only the diffracted rays, passing through an annulus of greater or less width surrounding it, enter the observing telescope. It will be seen that in both photographs the boundary appears as a perfectly black circle, with luminous rings on either side of it.

Let R be the radius of the circular aperture of the lens and assume that in the focal plane, there is a screen containing an annular aperture, R_1, R_2 being

the radii of the circles defining the annulus. Let ϕ be the angle of diffraction of parallel rays which meet at any point Q in the focal plane. Since the path-difference between the rays leaving a point (r, θ) and the centre of the diffracting aperture is evidently $r \cos\theta \sin\phi$, the diffracted disturbance at a point in the focal plane due to an area $r dr d\theta$ can be written in the form

$$r \sin 2\pi \left(\frac{t}{T} - \frac{r \cos\theta \sin\phi}{\lambda}\right) dr d\theta.$$

The total disturbance at Q in the focal plane is therefore

$$\int_0^{2\pi}\int_0^{R} r \sin 2\pi \left(\frac{t}{T} - \frac{r \cos\theta \sin\phi}{\lambda}\right) dr d\theta. \qquad (1)$$

The rays from the various elements $r'dr'd\theta'$ of the second aperture may be regarded as meeting in the field of the observing telescope proceeding at an angle ϕ' with the axis and producing the observed effect. The total disturbance in this direction due to the second aperture is therefore

$$\int_0^{2\pi}\int_{R_1}^{R_2}\int_0^{2\pi}\int_0^{R} rr' \sin 2\pi \left(\frac{t}{T} - \frac{r \cos\theta \sin\phi}{\lambda} - \frac{r' \cos\theta' \sin\phi'}{\lambda}\right) dr d\theta dr' d\theta'. \qquad (2)$$

Since ϕ and ϕ' are small quantities the above expression can be written as

$$\int_0^{2\pi}\int_{R_1}^{R_2}\int_0^{2\pi}\int_0^{R} rr' \sin 2\pi \left(\frac{t}{T} - \frac{\phi . r \cos\theta}{\lambda} - \frac{\phi' . r' \cos\theta'}{\lambda}\right) dr d\theta dr' d\theta'. \qquad (3)$$

This expression can be written in the form

$$\int_0^{2\pi}\int_{R_1}^{R_2} r' \sin 2\pi\left(\frac{t}{T}-\frac{\phi'.r'\cos\theta'}{\lambda}\right) dr'\,d\theta' \int_0^{2\pi}\int_0^{R}$$

$$r\cos\left(\frac{2\pi\phi.r\cos\theta}{\lambda}\right) dr d\theta, \quad (4)$$

the other integral being zero on account of symmetry of the diffracting aperture.

But the integral

$$\int_0^{2\pi}\int_0^{R} r\cos\left(2\pi\frac{\phi.r\cos\theta}{\lambda}\right) dr\, d\theta = \frac{2}{\pi}.\ \frac{R\lambda}{2\pi\phi}\ J_1\left(\frac{2\pi}{\lambda}R\phi\right).$$

Therefore the expression (4) becomes

$$\int_0^{2\pi}\int_{R_1}^{R_2} r' d\theta' dr' \sin 2\pi\left(\frac{t}{T}-\frac{\phi'.r'\cos\theta'}{\lambda}\right).\ \frac{1}{\phi} J_1\left(\frac{2\pi}{\lambda}R\phi\right),$$

neglecting a constant factor. (5)

If f is the focal length of the lens, then $\phi=\frac{r'}{f}$

The expression (5) can be written in the form

$$\sin 2\pi\frac{t}{T}\int_0^{2\pi}\int_{R_1}^{R_2} r' d\theta' dr' \cos\left(2\pi\frac{\phi'.r'\cos\theta'}{\lambda}\right)\frac{f}{r'} J_1\left(\frac{2\pi R}{\lambda f}.r'\right)$$

$$+\cos 2\pi\frac{t}{T}\int_0^{2\pi}\int_{R_1}^{R_2} r' d\theta' dr' \sin\left(2\pi\frac{\phi'.r'\cos\theta'}{\lambda}\right)\frac{f}{r'} J_1\left(\frac{2\pi R}{\lambda f}.r'\right).$$

Since the second aperture is also symmetrical about the axis, the second integral is zero, for the elements of it arising from two points situated at equal distances on opposite sides of a diameter are equal and of

opposite signs. Therefore the intensity as viewed in the direction ϕ' is

$$I = \left[\int_0^{2\pi} \int_{R_1}^{R_2} d\theta' dr' \cos\left(2\pi \frac{\phi' . r' \cos\theta'}{\lambda}\right) J_1\left(\frac{2\pi R}{\lambda f} . r'\right)\right]^2.$$

Integrating with respect to ϕ', we get

$$I = \left[\int_{R_1}^{R_2} J_0\left(\frac{2\pi\phi'}{\lambda} r'\right) J_1\left(\frac{2\pi R}{\lambda f} . r'\right) dr' \right]^2,$$

(neglecting a constant factor).

If the angular semi-aperture of the lens be denoted by ψ, then $R = f\psi$. Therefore

$$I = \left[\int_{R_1}^{R_2} J_0\left(\frac{2\pi\phi'}{\lambda} r'\right) J_1\left(\frac{2\pi\psi}{\lambda} r'\right) dr' \right]^2$$

Since $\frac{1}{\lambda}$ is a very large quantity, it is convenient to use semi-convergent expansions for J_0 and J_1. We have

$$J_0(x) = \sqrt{\frac{2}{\pi x}} \left[\cos\left(x - \frac{\pi}{4}\right) \left\{ 1 - \frac{1^2.3^2}{2!\,(8x)^2} + \frac{1^2.3^2.5^2.7^2}{4!\,(8x)^4} - \dots \right\} \right.$$
$$\left. + \sin\left(x - \frac{\pi}{4}\right) \left\{ \frac{1}{8x} - \frac{1^2.3^2.5^2}{3!\,(8x)^3} + \frac{1^2.3^2.5^2.7^2.9^2}{5!\,(8x)^5} - \dots \right\} \right],$$

$$J_1(x) = \sqrt{\frac{2}{\pi x}} \left[\sin\left(x - \frac{\pi}{4}\right) \left\{ 1 + \frac{3.5}{8}\frac{1}{16}\left(\frac{1}{x}\right)^2 \right. \right.$$
$$\left. + \frac{3.5.7.9.1.3.5}{8.16.24.32}\left(\frac{1}{x}\right)^4 - \dots \right\}$$
$$+ \cos\left(x - \frac{\pi}{4}\right) \left\{ \frac{3}{8}\cdot\frac{1}{x} - \frac{3.5.7.1.3.}{8.16.24}\left(\frac{1}{x}\right)^3 \right.$$
$$\left. \left. + \frac{3.5.7.9.11.1.3.5.7}{8.16.24.32.40}\left(\frac{1}{x}\right)^5 - \dots \right\} \right]$$

Thus when x is large,

$$J_0(x)=\sqrt{\frac{2}{\pi x}}\left[\cos\left(x-\frac{\pi}{4}\right)+\frac{1}{8}\,\frac{\sin\left(x-\frac{\pi}{4}\right)}{x}\right],$$

$$J_1(x)=\sqrt{\frac{2}{\pi x}}\left[\sin\left(x-\frac{\pi}{4}\right)+\frac{3}{8}\,\frac{\cos\left(x-\frac{\pi}{4}\right)}{x}\right],$$

Therefore,

$$I=\left[\int_{R_1}^{R_2} J_0\left(\frac{2\pi\phi'}{\lambda}x\right)J_1\left(\frac{2\pi\psi}{\lambda}x\right)dx\right]^2$$

$$=\frac{1}{\psi\phi'}\left[\frac{\lambda}{2\pi^2}\int_{R_1}^{R_2}\frac{\sin\frac{2\pi}{\lambda}(\psi-\phi')x}{x}dx\right.$$

$$-\frac{\lambda}{2\pi^2}\int_{R_1}^{R_2}\frac{\cos\frac{2\pi}{\lambda}(\psi+\phi')x}{x}dx$$

$$+\frac{\lambda^2}{32\pi^3}\left(\frac{1}{\phi'}+\frac{3}{\psi}\right)\int_{R_1}^{R_2}\frac{\cos\frac{2\pi}{\lambda}(\psi-\phi')x}{x}dx$$

$$-\frac{\lambda^2}{32\pi^3}\left(\frac{1}{\phi'}-\frac{3}{\psi}\right)\int_{R_1}^{R_2}\frac{\sin\frac{2\pi}{\lambda}(\psi+\phi')x}{x}dx$$

$$\left.+\text{ terms involving higher powers of }\lambda\right]^2.$$

Taking $R_1=\frac{3\lambda}{2\pi\psi}$, $R_2=\frac{50\lambda}{2\pi\psi}$: we obtain (neglecting a constant factor),

$$I=\frac{1}{\phi'\psi}\left[\left\{\mathrm{Si}\,50\left(1-\frac{\phi'}{\psi}\right)-\mathrm{Si}\,3\left(1-\frac{\phi'}{\psi}\right)\right\}\right.$$

$$-\left\{\mathrm{Ci}\,50\left(1+\frac{\phi'}{\psi}\right)-\mathrm{Ci}\,3\left(1+\frac{\phi'}{\psi}\right)\right\}$$

$$\left.+\lambda(\ \dots\quad\dots\ )+\ \dots\ \right]^2.$$

Calculating the values of this expression for different values of $\frac{\phi'}{\psi}$, we construct the following table :—

TABLE I.

ϕ'/ψ	$\sqrt{I}$	I (× const. factor.)	ϕ'/ψ	$\sqrt{I}$	I (× const. factor.)
0·00	−·1618	26,179	1·02	−·8891	790,501
0·20	−·2187	47,829	1·04	−1·5266	2,330,657
0·40	−·1190	14,161	1·06	−1·7009	2,891,056
0·60	+·2550	65,025	1·08	−1·5498	2,390,862
0·80	+·8192	671,085	1·10	−1·2687	1,609,597
0·90	+1·1385	1,290,220	1·20	−1·0471	1,096,438
0·92	+1·4169	2,007,612	1·40	−·3597	129,385
0·94	+1·6617	2,761,281	1·60	+·0582	3,387
0·96	+1·4055	1,975,447	1·80	+·2539	64,465
0·98	+·8154	664,878	2·00	+·3579	128,095
0·99	+·3964	157,134	2·40	+·1010	10,201
1·00	+·0732	5,358	2·60	−·0536	2,873
1·01	−·5241	274,581			

Plotting the values, we obtain a curve (fig. 1) representing the distribution of intensity along any given diameter. The fringes that appear on either side of the boundary are clearly shown, the most remarkable feature being the extreme rapidity with

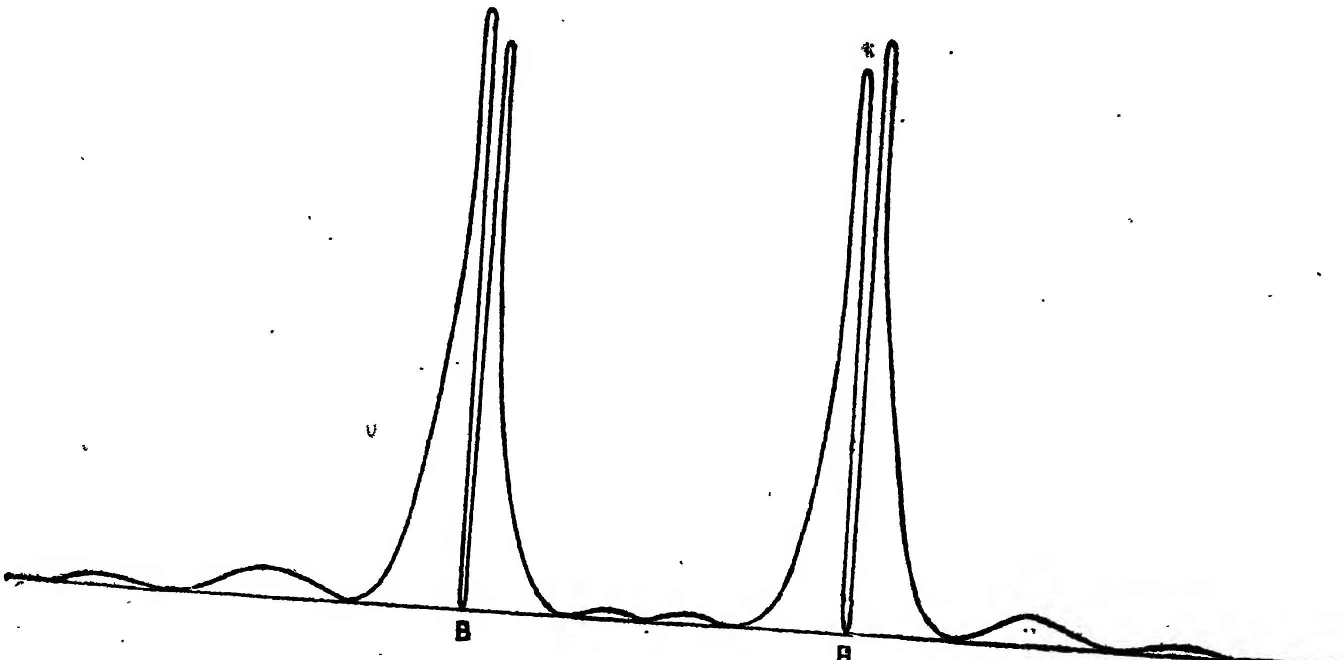

Fig 1.

which the intensity falls practically to zero on the boundary itself (BB in the figure) from a large value on either side of it. This feature depends on the inner radius R_1 of the annulus being small and the outer radius R_2 being very large, and is entirely confirmed by observation under these conditions.

When the radii R_1 and R_2 of the annulus in the focal plane do not differ much or if they are both large, the brightness falls off to zero on the boundary but not very suddenly. A larger number of well-defined fringes also appear on either side of the boundary in the former case. [See for instance, fig. 13 in the Plate]. This will be shown from the following calculations based on the data obtained from an actual experiment. The data were

$R = \cdot 94$ mm., $f = 272$ mm., $R_1 = 1\cdot 72$ mm.,
$R_2 = 2\cdot 61$ mm., $\lambda = \cdot 00045$ mm.

We thus obtain for this case

$$I = \frac{2}{\phi'\psi}\Big[\Big\{\mathrm{Si}\ 122\cdot 67\left(1-\frac{\phi'}{\psi}\right) - \mathrm{Si}\ 80\ 84\left(1-\frac{\phi'}{\psi}\right)\Big\}$$
$$-\Big\{\mathrm{Ci}\ 122\cdot 67\left(1+\frac{\phi'}{\psi}\right) - \mathrm{Ci}\ 80\cdot 84\left(1+\frac{\phi'}{\psi}\right)\Big\}$$
$$+\lambda\left(\ldots\ \ldots\ \ldots\right) + \text{etc.}\Big]^2.$$

The values of this expression for different values of $\frac{\phi'}{\psi}$ are shown in Table II in which the calculated and observed values of the ratio ϕ'/ψ at which the illumination is a maximum or minimum are given for comparison. It will be seen from the Table that $\sqrt{I}$ changes sign at the minima and these are therefore absolute zeroes.

TABLE II.

ϕ'/ψ	$\sqrt{I}$	I (× const. factor.)	Calculated values of ϕ'/ψ for Max. or Min.	Observed values of ϕ'/ψ for Max. or Min.	ϕ'/ψ	$\sqrt{I}$	I (× const. factor.)	Calculated values of ϕ'/ψ for Max. or Min.	Observed values of ϕ'/ψ for Max. or Min.
0·880	− ·0536	2,873	0·885 Min.		1·000	+ ·0053	28	1·000 Min.	1·000
0·890	− ·1257	15,801	0·892 Max.	0·894	1·005	− ·2134	45,539		
0·900	− ·0804	6,464	0·904 Min	0·901	1·010	− ·3448	118,889		
0·910	+ ·0908	8,245			1·015	− ·4158	172,889	1·017 Max.	1·015
0·920	+ ·2179	47,481	0·922 Max.	0·930	1·020	− ·3673	134,908		
0·930	+ ·1543	23,808			1·025	− ·2209	48,797		
0·940	− ·0779	6,068	0·935 Min.	0·940	1·030	− ·0491	2,411	1·028 Min.	1·030
0·950	− ·3149	99,168	0·953 Max.	0·957	1·040	+ ·2866	82,139		
0·960	− ·2761	76,231			1·050	+ ·3251	105,690	1·047 Max.	1·046
0·970	+ ·0599	3,588	0·971 Min.	0·971	1·060	+ ·0875	7,656	1·063 Min.	1·061
0·975	+ ·2423	58,709			1·070	− ·1478	21,844		
0·980	+ ·3779	142,809			1·080	− ·2141	45,839	1.077 Max.	1·078
0·985	+ ·4268	182,158	0·983 Max.	0·985	1·090	− ·0859	7,379		
0·990	+ ·3548	125,883			1·100	+ ·0854	7,293	1·095 Min.	1·096
0·995	+ ·2244	50,355			1·110	+ ·1354	18,333	1·107 Max.	1·109
1·000	+ ·0053	28	1·000 Min.	1·000	1·120	+ ·0596	3,552	1·125 Min.	1·132

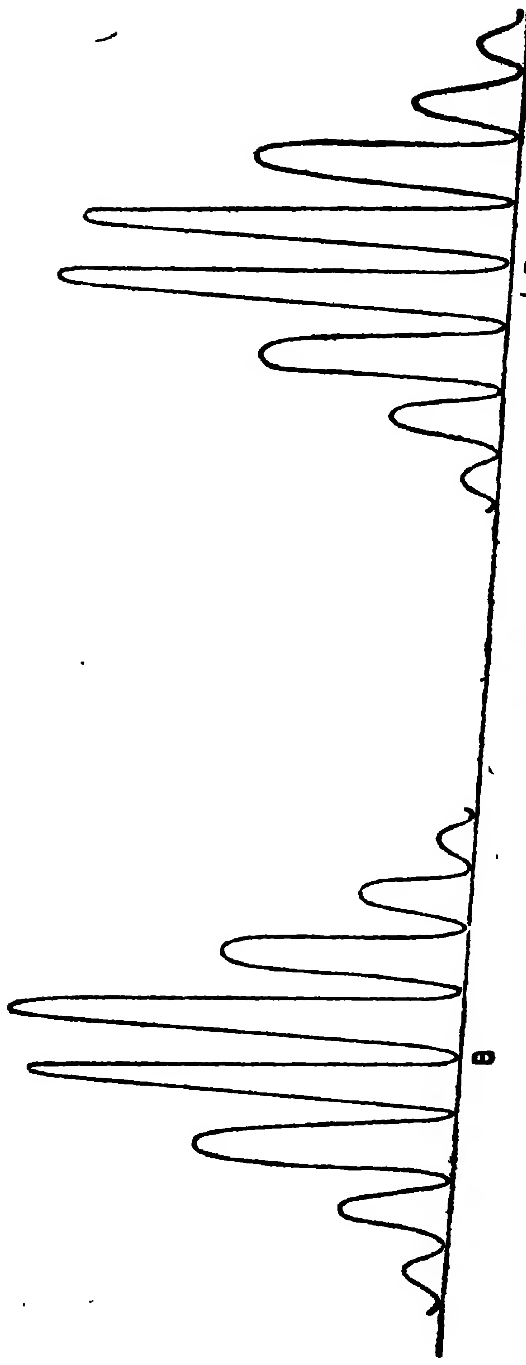

Fig. 2

The values for I shown in Table II have been plotted in fig. 2.

The investigation given above may be modified to suit the case in which we have one or more slits (instead of an annulus) in the focal plane, by suitably altering the limits of integration in the expression (5) given above. The writer hopes to give the detailed numerical calculations in a later paper. It is possible, however, to understand in a general way the reason for the peculiar configuration of the fringes for these cases shown in figs. 6, 12 and 15 in the Plate. If instead of a slit we have in the focal plane a small aperture at (r', θ') through which the boundary is viewed, the luminosity of the latter appears confined to certain regions lying in the neighbourhood of the two points $r=\mathrm{R}$, $\theta=\theta'$ and $\theta=\pi+\theta'$ and which are more or less well-defined according to the size and position of the aperture. The further the aperture is from the centre of the focal plane, the feebler is the luminosity observed through it. Accordingly, if we regard the horizontal slit placed in the focal plane as consisting of a number of elements along its length, the vanishing of the luminosity of the boundary at the ends of the horizontal diameter is seen to follow as a consequence. At and near these points also, the radial width of the luminosity should obviously be the least as the latter is, roughly speaking, in inverse proportion to the corresponding radial width of the aperture in the focal plane. This gives us a qualitative explanation of the lunette-shaped form of the fringes in these cases.

Figs. 5, 8, 11 and 14 in the Plate illustrate the remarks made above regarding the localisation of the luminosity of the boundary observed in certain cases. Fig. 5 represents the effect observed when there were two small circular apertures in the focal plane not lying on the same radius vector. Accordingly, we have on the boundary four separate regions of luminosity. Fig. 8 represents a photograph obtained when a ring of six circular holes was placed symmetrically in the focal plane. Each of the six spots seen along the boundary is crossed by very fine fringes due to the interference of the effects produced by the pair of apertures at the end of each diameter. Fig. 14 was obtained when the ring of holes was slightly displaced in the focal plane. Twelve spots appear on the boundary. Fig 11 represents the effect observed when the screen in the focal plane was so placed that two out of the three pairs of apertures fell on lines passing through the centre of the field. Accordingly, only eight spots are seen, the four larger ones being crossed by fine interference fringes.

§ 3. *Case of the Rectangular Boundary.*

Some beautiful and striking colour effects are noticed in the 'knife-edge' test when the surface under observation is bounded by parallel straight edges. (The source of light should be either a point or a fine slit parallel to the boundaries of the surface and to the knife-edge, so that the diffraction fringes formed in the focal plane are sharply defined). When the knife-edge is put in the focal plane so as to cut off all the diffraction bands on one side and also a few of

those on the other, it is observed that the boundaries of the surface appear luminous and white, but the region inside the boundaries shows colour, this being practically of the same tint throughout but most marked midway between the boundaries. The whole of the field between the boundaries changes colour as the knife-edge is moved so as to cut off more bands of the diffraction pattern formed at the focus. The colour is successively the following as the knife-edge is moved into the focal plane :—brilliant white, yellowish white, yellow, dark yellow, orange-red, indigo, blue, green, greenish yellow, yellow, orange-yellow, orange, orange-red, purplish red, purple, indigo-blue, bluish green, grass-green, greenish-yellow, orange-yellow, purple, greenish blue, green and so on. The field outside the boundaries also shows a colour (though much less vividly) which is in general complementary to that observed between the boundaries. When the source of light is monochromatic, it is found that the luminosity of the entire field of observation between the boundaries undergoes large fluctuations as the knife-edge is moved in the focal plane. The colour effects noticed in white light are obviously due to these fluctuations of intensity not being in the same phase for different parts of the specturm.

The theory of Foucault's test as developed by Lord Rayleigh is found to be capable of explaining these remarkable colour phenomena. The expression given

by Lord Rayleigh for the intensity of the field as viewed in the direction ϕ is

$$I=\left[\mathrm{Si}\left\{\frac{2\pi}{\lambda}\theta\left(1+\frac{\phi}{\theta}\right)\xi_2\right\}-\mathrm{Si}\left\{\frac{2\pi}{\lambda}\theta\left(1+\frac{\phi}{\theta}\right)\xi_1\right\}\right.$$

$$\left.+\mathrm{Si}\left\{\frac{2\pi}{\lambda}\theta\left(1-\frac{\phi}{\theta}\right)\xi_2\right\}-\mathrm{Si}\left\{\frac{2\pi}{\lambda}\theta\left(1-\frac{\phi}{\theta}\right)\xi_1\right\}\right]^2$$

$$+\left[\mathrm{Ci}\left\{\frac{2\pi}{\lambda}\theta\left(1-\frac{\phi}{\theta}\right)\xi_2\right\}-\mathrm{Ci}\left\{\frac{2\pi}{\lambda}\theta\left(1-\frac{\phi}{\theta}\right)\xi_1\right\}\right.$$

$$\left.-\mathrm{Ci}\left\{\frac{2\pi}{\lambda}\theta\left(1+\frac{\phi}{\theta}\right)\xi_2\right\}+\mathrm{Ci}\left\{\frac{2\pi}{\lambda}\theta\left(1+\frac{\phi}{\theta}\right)\xi_1\right\}\right]^2,$$

where ξ_1, ξ_2 define the aperture in the focal plane and θ is the angular semi-aperture of the lens. In practice ξ_2 is large. To illustrate the fact that the luminosity of the field between the boundaries undergoes fluctuations as ξ_1 is gradually increased, I have prepared the following table showing the intensity of different points of the field as calculated from the expression given above, taking $\xi_2=\frac{300\lambda}{2\pi\theta}$ and $\xi_1=\frac{3\lambda}{2\pi\theta}x$, where x has the values 1, 1·63, 2, 2·62 and 3 in succession, these being approximately the values for which the intensity at the centre of the field is greatest or least.

It will be seen from the figures in Table III that the intensity of the entire field between the limits $\phi/\theta=\pm1$ becomes alternately greater and less as ξ_1 is increased. (This fact has not been brought out in Lord Rayleigh's paper). The region outside the boundaries does not show such a marked variation. In fact, observation shows that when ξ_2 is large, a variation of ξ_1 produces a relatively insignificant effect on the intensity of the field outside the boundaries.

TABLE III.

$r.$	$\frac{\theta}{\phi}=0.$	$\frac{\theta}{\phi}=\pm .1.$	$\frac{\theta}{\phi}=\pm .2.$	$\frac{\theta}{\phi}=\pm .3.$	$\frac{\theta}{\phi}=\pm .5.$	$\frac{\theta}{\phi}=\pm .8.$	$\frac{\theta}{\phi}=\pm .9.$	$\frac{\theta}{\phi}=\pm 1.$	$\frac{\theta}{\phi}=\pm 1.1.$	$\frac{\theta}{\phi}=\pm 1.2.$	$\frac{\theta}{\phi}=\pm 1.5.$	$\frac{\theta}{\phi}=\pm 1.8.$	$\frac{\theta}{\phi}=\pm 2.$
1	·31	·34	·320	·350	·4718	1·0150	1·310	20·23	1·6850	·7550	·1742	·0712	·0384
1·63	0	·0001	·0052	·020	·0625	·2996	1·330	16·82	1·6003	·6205	·1969	·0872	·0601
2	·09	·07	·0830	·095	·1470	·3945	1·009	15·30	·8369	·3277	·0519	·0196	·0349
2·62	0	·0009	·0025	·007	·0058	·1530	·604	13·73	·7270	·2350	·0418	·0132	·0151
3	·01	.033	·0315	·038	·0186	·1782	·544	12·35	·5443	·1781	·0401	·0316	·0120

If, however, ξ_2 be not large, experiment and theory agree in showing that a variation of either ξ_1 alone or of ξ_1 and ξ_2 ($\xi_2 - \xi_1$ remaining constant) results in a marked fluctuation of the intensity of the field outside the boundaries, and the colours observed in this region with white light become more prominent. It should be remarked here that when ξ_2 is not large, the regions inside and outside the boundaries (observed in white light) are not generally of uniform tint throughout, as diffraction fringes appear showing a regular succession of colours, although a preponderance of a particular colour within the boundaries and of a complementary colour in the region outside is noticed. As the knife-edge is moved in, the relative intensities of the different colours change to an enormous extent, and the positions of the different fringes shift to and fro. The changes in the position and the colour of the bands within the boundaries are most interesting to watch when their number is small. If it is arranged to alter both ξ_1 and ξ_2 ($\xi_2 - \xi_1$ remaining constant and small), a fluctuation in the number of the fringes between the boundaries from one to two, or two to three, and *vice versa*, may be observed, these changes synchronising with the fluctuation in the intensity of the bands.

Fig. 23 in the Plate represents the luminosity observed at the edges of a rectangular diffracting aperture in Foucault's test. In taking this photograph, ξ_1 was small and ξ_2 large. The luminosity accordingly appears highly condensed at the edges. Fig. 20 reproduces a photograph obtained when ξ_1 and ξ_2 did not differ very considerably. Diffraction fringes are

clearly seen on either side of the boundaries in this case. Fig. 17 reproduces a photograph of the aperture obtained with two parallel slits in the focal plane on the same side. It will be noticed that the central fringe which coincides with each boundary is white. Figs. 21 and 24 represent photographs obtained when the central band and a few fringes on either side of the diffraction pattern at the focal plane were cut off by a wire parallel to the edges of the aperture. It will be observed that the positions of the boundaries in these two photographs appear as fine black lines with luminous bands on either side. The same feature but with the dark lines at the boundaries much broader is shown in figs. 18 and 25, which were secured by placing two parallel slits symmetrically in the focal plane, that is, one on either side of the centre of the field.

We proceed to consider the explanation of the black lines marking the positions of the boundaries in the four photographs mentioned in the preceding para. In the focal plane we have two apertures extending fron ξ_1 to ξ_2 and from $-\xi_1$ to $-\xi_2$ respectively. On account of the symmetry, the Ci-functions disappear from the expression for the intensity of field as viewed in the direction ϕ, which may be written in the form

$$I=4\left[\mathrm{Si}\left\{\frac{2\pi\theta}{\lambda}\left(1+\frac{\phi}{\theta}\right)\xi_2\right\}-\mathrm{Si}\left\{\frac{2\pi\theta}{\lambda}\left(1+\frac{\phi}{\theta}\right)\xi_1\right\}\right.$$

$$\left.+\mathrm{Si}\left\{\frac{2\pi\theta}{\lambda}\left(1-\frac{\phi}{\theta}\right)\xi_2\right\}-\mathrm{Si}\left\{\frac{2\pi\theta}{\lambda}\left(1-\frac{\phi}{\theta}\right)\xi_1\right\}\right]^2,$$

where θ is the angular semi-aperture of the lens. When $\phi/\theta \pm 1$, that is, at the boundaries, this expression becomes very small but the suddenness with which

the illumination falls to zero at these points depends very much on the magnitudes of ξ_1 and ξ_2. To illustrate this statement, I have calculated the distribution of intensity for a hypothetical case in which $\xi_1=\frac{\lambda}{\theta}$ and $\xi_2=\frac{50\lambda}{\theta}$. The values are shown in Table IV (in which the factor 4 in the expression for the intensity has been neglected) and these have been plotted in fig. 3.

TABLE IV.

ϕ/θ	I	ϕ/θ	I
1·000	0·0045	1·000	0·0045
1·002	1·7956	0·998	2·2201
1·005	1·5129	0·995	1·8496
1·010	2·9584	0·990	3·4225
1·020	1·5376	0·980	2·1609
1·030	2·0164	0·970	2·4025
1·100	0·8281	0·900	1·0050
1·300	0·0020	0·700	0·0000
1·500	0·0605	0·500	0·0357
1·800	0·0000	0·200	0·0057
2·000	0·0182	0·000	0·0853

Another case in which the disparity between ξ_1 and ξ_2 was much smaller was chosen for experimental verification of the positions of the diffraction maxima and minima given by theory. It is found that the

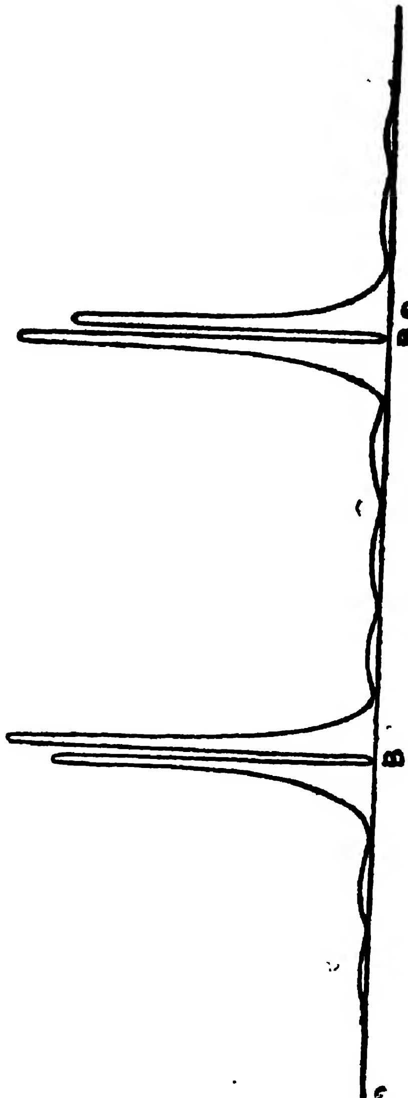

Fig. 3.

TABLE V.

$\xi_1 = \cdot 654$mm., $\xi_2 = \cdot 963$mm., $f = 13\cdot 4$cms., $\lambda = \cdot 00045$mm., width of the aperture $= 0\cdot 955$mm.

ϕ/θ	$\sqrt{I}$	I (× const. factor.)	Calculated values of ϕ/θ for max. & mim.	Observed values of ϕ/θ for max. & min.	ϕ/θ	$\sqrt{I}$	I (× const. factor.)	Calculated values of ϕ/θ for max. & min.	Observed values of ϕ/θ for max. & min.
·760	−·0002	0	·760 min.	·756	1·000	−·0145	2	1·000 min.	1·000
·780	+·1468	204			1·005	−·0918	84		
·800	+·2123	449	·800 max.	·802	1·010	−·1528	233		
·820	+·1463	201			1·020	−·2587	669		
·840	−·0018	0	·840 min.	·843	1·030	−·3701	1370		
·860	−·1601	256			1·040	−·6898	4758	1·04 max.	1·038
·880	−·3084	957	·888 max.	·882	1·050	−·3648	1331		
·900	−·2369	559			1·060	−·2517	634		
·920	−·0065	0	·923 min.	·927	1·070	−·1513	229		
·930	+·1337	179			1·080	−·0059	0	1·080 min.	1·076
·940	+·2386	567			1·100	+·2431	589		
·950	+·3416	1167			1·120	+·3196	1021	1·114 max.	1·115
·960	+·6707	4498	·960 max.	·961	1·140	+·1713	293		
·970	+·3431	1177			1·160	−·0024	0	1·16 min.	1·157
·980	+·2398	575			1·180	−·1642	270		
·990	+·1350	182			1·200	−·2128	453	1·198 max.	1·205
·995	+·0620	38			1·220	−·1478	218		
1·000	−·0145	2	1·000 min.	1·000	1·240	−·0002	0	1·24 min.	1·238

illumination falls off to practically zero value on the boundaries but much less suddenly than in the case previously discussed. The experimental data, the calculated intensities of the illumination and the theoretical and experimentally observed positions of the maxima and minima are shown in Table V. The agreement is fairly satisfactory. For comparison with the preceding case, the illumination curve has been plotted in fig. 4. As in the case of the circular boundary, the minima of illumination are absolute zeroes.

§ 4. *Other forms of Boundary.*

The cases in which the surface is bounded by forms of apertures other than those considered previously are of interest from the point of view of the general theory of diffraction. Figs. 19 and 22 in the Plate represent photographs of the effect observed when the surface is bounded by a quadrilateral and triangular apertures respectively. These photographs were obtained using a point source of light and an annular aperture placed symmetrically in the focal plane. It will be noticed that the boundaries appear as black lines with luminous fringes on either side, thus showing a complete analogy with the cases of the circular and rectangular boundaries previously considered.

In order more fully to study the luminosity at the boundaries of the triangular, qaudrilateral and other forms of aperture, an arrangement was devised in which a screen containing a small circular hole could be placed excentrically in the focal plane and rotated in this plane. This hole comes successively over different

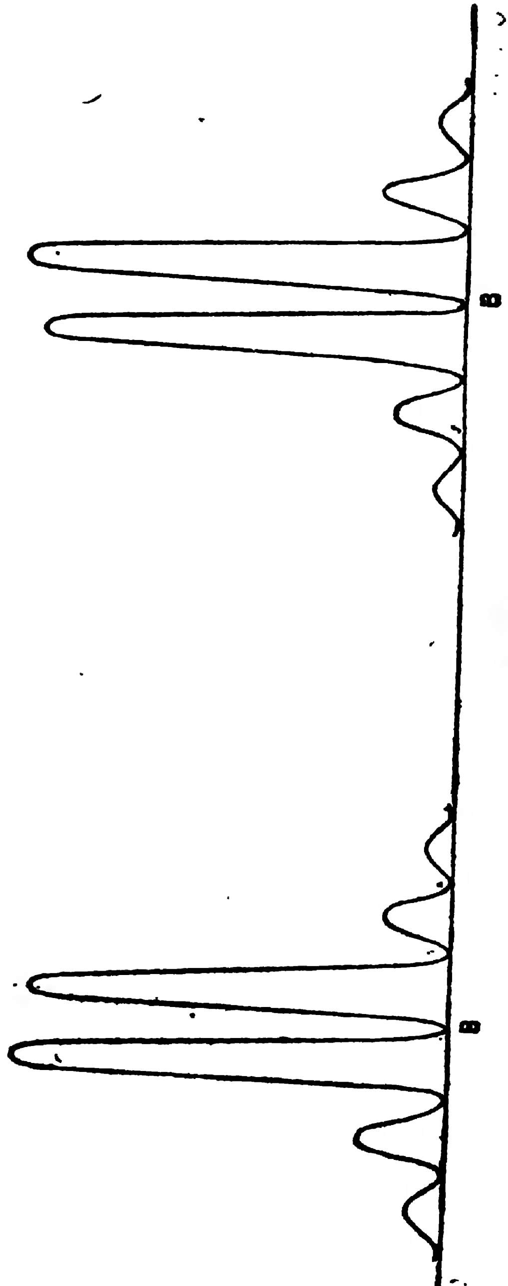

Fig. 4.

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parts of the diffraction pattern formed at the focus, and the luminosity at the boundaries observed through it undergoes a series of changes. For instance, with a triangular aperture, it is known that the diffraction pattern at the focus consists of a six-rayed 'star', the 'rays' being perpendicular to the three sides of the triangle respectively. When the hole comes over any one of the rays, the corresponding boundary appears luminous, but in other cases it becomes practically invisible. Similarly with a quadrilateral aperture, the diffraction pattern is a 'star' with eight rays perpendicular to its four sides, and each of the sides appears luminous when the excentrically placed hole in the focal plane comes over the corresponding ray of the pattern.

Whether any particular part of the boundary appears luminous or not seems in general to depend on the normal to the boundary at that point being parallel to the radius vector from the centre of the focal plane to the aperture in the screen through which it is viewed. This is stated here as an experimental fact, the detailed mathematical explanation of which is deferred till a future occasion. An interesting illustration of its generality is furnished by the observation that minute irregularities in the boundary often appear luminous when the adjoining parts which are straight are invisible from any given point in the focal plane. A discussion of the cases in which the boundary is a complicated figure such as a grating or a series of parallel apertures is also reserved for a future occasion.

§ 5. *On the Theory of Foucault's Test with non-linear Retardations.*

Lord Rayleigh has considered in his paper the cases in which the wave before reaching the focus suffers retardations of a linear type over its various parts. The principal result obtained by him is that any direction in which the retardation has a discontinuous change is strongly marked by excess of brightness. If, however, the retardations are of *a non-linear* type, the theory becomes considerably more complicated. The various parts of the wave would arrive at foci not all lying in the plane of the knife-edge. As a first step towards a detailed discussion of such cases, I propose in this section to consider the effects noticed when the retardations are non-linear but of such magnitudes that the geometrical foci of the different parts of the wave are coincident but lie in a plane in advance of or behind the plane of the knife-edge. Practically speaking, this case is identical with that in which the wave suffers no retardations whatever but the knife-edge is introduced in a plane lying behind or in advance of the focus. Actual experimental observations in the case of a rectilinear boundary under these conditions show that when the knife-edge is sufficiently advanced so as to cut off the geometrical pencil of rays, the two edges of the field still appear luminous but *differ markedly in their brilliancy.* This difference becomes greater and greater as the knife-edge is put in a plane further and further from the focus. The effect is reversed if the knife edge is put in front of instead of behind the focal plane and has no doubt been frequently noticed by those who have applied

Foucault's test in practice. It should be remarked also that when the knife-edge in considerably advanced in any given plane, the inequality of the luminosity of the two edges diminishes. The mathematical theory of these effects is given below.

Let A represent the lens with its rectangular aperture which brings parallel rays to a focus O. Let a screen containing an aperture parallel to the aperture of the lens be placed at a distance a in advance of the focus. A is the centre of the first aperture and Q any point on it, so that AQ$=s$. If P be any point on the second aperture and B the centre of the screen, then putting BP$=\xi$ and AO$=f$, we get

$$PQ^2=QO^2+OP^2-2QO.OP\cos POQ$$

$$=f^2+a^2+\xi^2+2f.\sqrt{a^2+\xi^2}\cos\left(\frac{s}{f}+\tan^{-1}\frac{\xi}{a}\right)$$

$$=(f+\sqrt{a^2+\xi^2})^2-4f.\sqrt{a^2+\xi^2}\sin^2\tfrac{1}{2}\left(\frac{s}{f}+\tan^{-1}\frac{\xi}{a}\right).$$

Since $\sin^2\frac{1}{2}\left(\frac{s}{f}+\tan^{-1}\frac{\xi}{a}\right)$ is small provided $\frac{\xi}{a}$ is small, we have, extracting the square root

$$PQ=f+\sqrt{a^2+\xi^2}-\frac{2f.\sqrt{a^2+\xi^2}}{f+\sqrt{a^2+\xi^2}}\sin^2\tfrac{1}{2}\left(\frac{s}{f}+\tan^{-1}\frac{\xi}{a}\right).$$

Now, assuming that ξ/a is small, we get

$$PQ=f+\sqrt{a^2+\xi^2}-\frac{f\sqrt{a^2+\xi^2}.\,\xi^2}{2(f+\sqrt{a^2+\xi^2})a^2}-\frac{\xi\sqrt{a^2+\xi^2}}{a(f+\sqrt{a^2+\xi^2})}.\,s$$

$$-\frac{\sqrt{a^2+\xi^2}}{2f(f+\sqrt{a^2+\xi^2})}.\,s^2.$$

Thus we see that

$$PQ=f+A+Bs+Cs^2,$$

where $$A=\sqrt{a^2+\xi^2}-\frac{\sqrt{a^2+\xi^2}.\,f.\xi^2}{2(f+\sqrt{a^2+\xi^2})a^2},$$

$$B = -\frac{\xi\sqrt{a^2+\xi^2}}{a(f+\sqrt{a^2+\xi^2})},$$

$$C = -\frac{\sqrt{a^2+\xi^2}}{2f.\,(f+\sqrt{a^2+\xi^2})}.$$

Therefore the vibration at the point ξ of the second aperture will be represented by

$$\int_{-s}^{s} \cos 2\pi\left(\frac{t}{\tau} - \frac{f+A+Bs+Cs^2}{\lambda}\right) ds.$$

If T be written for $\left(\frac{t}{\tau}-\frac{f}{\lambda}\right)\lambda$, the above integral can be written in the form

$$\cos\frac{2\pi}{\lambda}T\int_{-s}^{s} \cos 2\pi\left(\frac{A+Bs+Cs^2}{\lambda}\right) ds$$

$$+\operatorname{Sin}\frac{2\pi}{\lambda}T\int_{-s}^{s} \sin 2\pi\left(\frac{A+Bs+Cs^2}{\lambda}\right) ds.$$

The rays from the various points of the second aperture may be regarded as a parallel pencil inclined to the axis at a small angle ϕ. When we proceed to enquire what is to be observed at an angle ϕ, we have to consider the expression

$$\operatorname{Cos}\kappa T\int_{\xi_1}^{\xi_2}\int_{-s}^{s} \cos\kappa\,(A+Bs+Cs^2-\phi\xi)\,ds\,d\xi$$

$$+\sin\kappa T\int_{\xi_1}^{\xi_2}\int_{-s}^{s} \sin\kappa\,(A+Bs+Cs^2-\phi\xi)\,ds\,d\xi,$$

where $\kappa = \frac{2\pi}{\lambda}$ and ξ_1, ξ_2 define the limits of the second aperture.

The intensity I represented as the sum of the squares of the integrals, is given by

$$I=\left[\int_{\xi_1}^{\xi_2}\int_{-s}^{s}\cos\kappa\,(A+Bs+Cs^2-\phi\xi)\,ds\,d\xi\right]^2$$

$$+\left[\int_{\xi_1}^{\xi_2}\int_{-s}^{s}\sin\kappa\,(A+Bs+Cs^2-\phi\xi)\,ds\,d\xi\right]^2.$$

The integration can be carried out with respect to s on putting $s=z-\alpha$ and choosing α, so that the term containing the first power of z in the expression $A+B\,(z-\alpha)+C\,(z-\alpha)^2-\phi\xi$ vanishes. The integrals are thus reduced to integrals of the Fresnel class and can be integrated in semi-convergent series. Since κ is a large quantity, we retain only a few terms of the series, and the subsequent integration with respect to ξ is effected by integrating by parts.

We thus find that the intensity is proportional to the sum of the squares of the expressions (I) and (II) given below

$$\text{(I)}\quad \frac{c_2}{2C_2\kappa}\Big[-\cos\kappa\,(A_2+B_2s+C_2s^2-\phi\xi_2)\cdot s\Big]_{-s}^{s}$$

$$+\left\{a_2-\left(b_2-\frac{B_2c_2}{2C_2}\right)\frac{B_2}{2C_2}\right\}\left[-\frac{\cos\kappa\,(A_2+B_2s+C_2s^2-\phi\xi_2)}{\kappa\,(B_2+2C_2s)}\right]_{-s}^{s}$$

$$+\left(b_2-\frac{B_2c_2}{2C_2}\right)\frac{1}{C_2\kappa}\Big[-\cos\kappa\,(A_2+B_2s+C_2s^2-\phi\xi_2)\Big]_{-s}^{s}$$

$$-\frac{c_1}{2C_1\kappa}\Big[-\cos\kappa\,(A_1+B_1s+C_1s^2-\phi\xi_1)\cdot s\Big]_{-s}^{s}$$

$$-\left\{a_1-\left(b_1-\frac{B_1c_1}{2C_1}\right)\frac{B_1}{2C_1}\right\}\left[-\frac{\cos\kappa(A_1+B_1s+C_1s^2-\phi\xi_1)}{\kappa(B_1+2C_1s)}\right]_{-s}^{s}$$

$$-\left(b_1-\frac{B_1c_1}{2C_1}\right)\frac{1}{2C_1\kappa}\left[-\cos\kappa(A_1+B_1s+C_1s^2-\phi\xi_1)\right]_{-s}^{s}$$

$$(\mathrm{II})-\frac{c_2}{2C_2\kappa}\left[\sin\kappa(A_2+B_2s+C_2s^2-\phi\xi_2).s\right]_{-s}^{s}$$

$$-\left\{a_2-\left(b_2-\frac{B_2c_2}{2C_2}\right)\frac{B_2}{2C_2}\right\}\left[\frac{\sin\kappa(A_2+B_2s+C_2s^2-\phi\xi_2)}{\kappa(B_2+2C_2s)}\right]_{-s}^{s}$$

$$-\left(b_2-\frac{B_2c_2}{2C_2}\right)\frac{1}{2C_2\kappa}\left[\sin\kappa(A_2+B_2s+C_2s^2-\phi\xi_2)\right]^{s}$$

$$+\frac{c_1}{2C_1\kappa}\left[\sin\kappa(A_1+B_1s+C_1s^2-\phi\xi_1).\right]_{-s}$$

$$+\left\{a_1-\left(b_1-\frac{B_1c_1}{2C_1}\right)\frac{B_1}{2C_1}\right\}\left[\frac{\sin\kappa(A_1+B_1s+C_1s^2-\phi\xi_1)}{\kappa(B_1+2C_1s)}\right]_{-s}^{s}$$

$$+\left(b_1-\frac{B_1c_1}{2C_1}\right)\frac{1}{C_1\kappa}\left[\sin\kappa(A_1+B_1s+C_1s^2-\phi\xi_1)\right]_{-s}^{s}.$$

where

$$A_2=a+\tfrac{1}{2}\frac{1}{f+a}\xi_2^2,$$

$$B_2=-\frac{1}{f+a}\xi_2,$$

$$C_2=-\frac{a}{2f(f+a)}\left[1+\frac{f}{2a^2(f+a)}\xi_2^2\right],$$

$$A_1 = a + \tfrac{1}{2}\frac{1}{f+a}\xi_1^2,$$

$$B_1 = -\frac{1}{f+a}\xi_1,$$

$$C_1 = -\frac{a}{2f(f+a)}\left[1 + \frac{f}{2a^2(f+a)}\xi_1\right],$$

$$a_2 = \frac{f+a}{\xi_2 - \phi(f+a)},$$

$$b_2 = \frac{f+a}{\{\xi_2 - \phi(f+a)\}^2},$$

$$c_2 = \frac{f+a}{\{\xi_2 - \phi(f+a)\}^3} + \frac{\xi_2(f+a)}{2a(f+a)\{\xi_2 - \phi(f+a)\}^2},$$

$$a_1 = \frac{f+a}{\xi_1 - \phi(f+a)},$$

$$b_1 = \frac{f+a}{\{\xi_1 - \phi(f+a)\}^2},$$

$$c_1 = \frac{f+a}{\{\xi_1 - \phi(f+a)\}^3} + \frac{\xi_1(f+a)}{2a(f+a)\{\xi_1 - \phi(f+a)\}^2}.$$

This expression has been used to determine the ratio of the intensities of the two edges for different positions of the advancing edge at different distances from the focal plane. The ratio of the brightness of the two edges was also determined experimentally by photometric comparison. For this purpose, a double-image prism was used to obtain a pair of images of the luminous edges polarised in perpendicular planes which were then observed through a nicol. The results are shown in Table VI. The agreement between theory and experiment is fairly satisfactory.

TABLE VI.

$2s = 3{\cdot}47$ mm., $f = 43{\cdot}3$ cm., $\lambda = {\cdot}0006$ mm.

a	ξ_1	ξ_2	Observed ratio of the intensity of the two edges.	Calculated ratio of the intensity of the two edges.
−4·0 cm.	0·85 mm.	5·65 mm.	0·25	0·21
−4·0 "	2·65 "	5·65 "	0·41	0·38
−2·5 "	0·72 "	5·38 "	0·32	0·30
−2·5 "	2·43 "	5·38 "	0·53	0·48
−1·5 "	1·00 "	5·95 "	0·50	0·45
−1·5 "	2·87 "	5·82 "	0·65	0·59
0 "	...	...	1·00	1·00
+2·5 "	·76 "	5·76 "	1·32	1·28
+2·5 "	2·76 "	5·76 "	1·14	1·11
+4·5 "	·61 "	5·61 "	2·37	2·29
+4·5 "	2·6 "	5·61 "	1·42	1·37

§ 6. *On the Emission of Light by the Edges of Diffracting Apertures.*

A few further observations on the apparent emission of light from the edges of a diffracting aperture may be mentioned here. In the previous sections, it has been shown that the boundary of a diffracting surface appears *as a black line* (surrounded by luminous fringes on either side), when observed solely by diffracted light admitted through apertures placed *symmetrically* in the focal plane. A similar result is also found when

the screen which blocks out the geometrical pencil of rays is placed symmetrically in any plane either in or beyond the focus. It would appear from this observation that we may regard the edge of a diffracting aperture as sending out two streams of light in directions more or less nearly normal to itself (one on each side of the wave normal), and that these streams are in *opposite phases.* This is distinctly suggested by Sommerfeld's well-known investigation on the diffraction of light by semi-infinite screen, though of course the results are not strictly applicable in the case of a convergent wave limited by rectilinear boundaries at a finite distance from each other. In this investigation[1] it is shown that the illumination in any part of the field (excluding a very limited region on either side of the dividing planes) may be found by superposing upon the direct and reflected streams of light, a radiation emitted by the edge of the screen, the amplitude of this being given by the expression

$$\frac{1}{4\pi}\cos\left\{2\pi\left(\frac{r}{\lambda}-\frac{t}{T}\right)+\frac{\pi}{4}\right\}\sqrt{\frac{\lambda}{r}}\left[\frac{\pm 1}{\cos\frac{\phi+\phi'}{2}}-\frac{1}{\cos\frac{\phi-\phi'}{2}}\right].$$

When ϕ is nearly equal to $\pi-\phi'$ or $\pi+\phi'$, one of the two terms inside the square brackets becomes very large compared with the other, and the latter may then be neglected. When ϕ changes from a value less than $\pi-\phi'$ to a value greater than $\pi-\phi'$ or if it changes from a value less than $\pi+\phi'$ to a value greater than $\pi+\phi'$, the expression for the amplitude changes sign, showing that the phase of the radiation emitted

1 Math. Ann., Bd. 47, (1896).

by the edge changes by π when we pass from one side of the plane of transition to the other.[1]

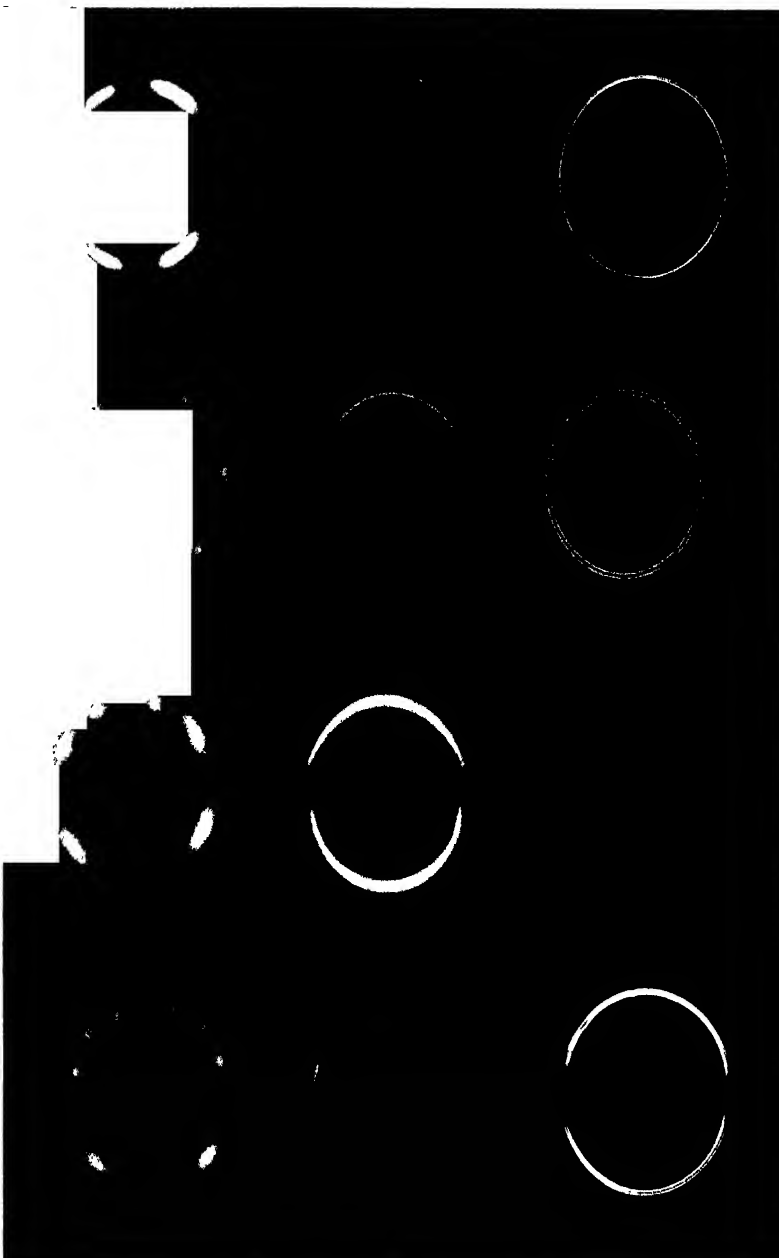
I have also attempted to study the phenomena of the flow of energy in the optical field due to rectangular and circular boundaries in convergent light by placing a narrow screen, or a wide screen with a narrow aperture in it in some selected part of the field and tracing the phenomena observed in its rear. Interesting results have been noticed particularly in the case of a circular boundary but a description of this is reserved for a future occasion.

The investigation was carried in the Laboratory of the Indian Association for the Cultivation of Science. The author has much pleasure in gratefully acknowledging the helpful interest taken by Prof. C. V. Raman in the progress of the work.

CALCUTTA,
The 24th January, 1918.

1 For the case of the rectangular boundary the change in the phase of the vibration *at the focal plane* in passing across the zero point has been remarked upon by Lord Rayleigh in his paper. Phil. Mag., Feb., 1917, p. 171.

Figs.



5, 6, 7

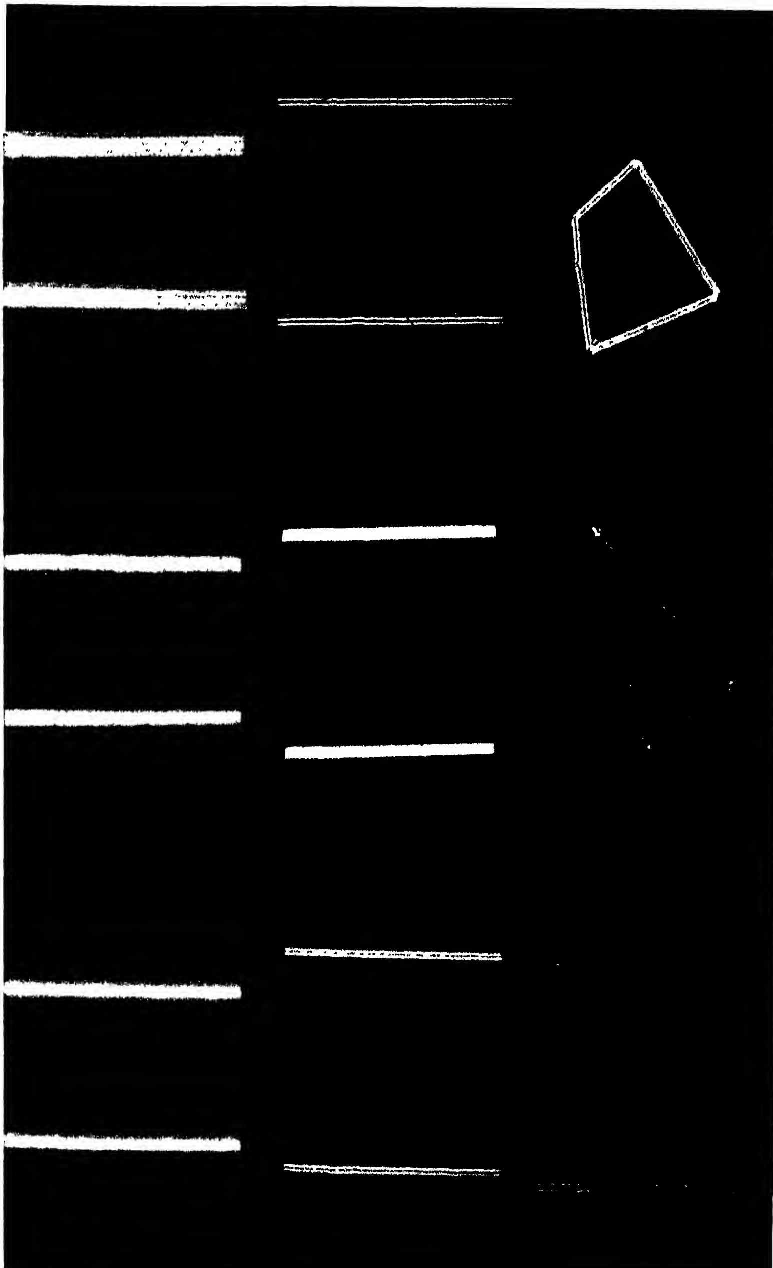
8, 9, 10

11, 12, 13

14, 15, 16

Illustrating the Emission of Light by the Boundary of a Circular Diffracting Aperture

Figs.



17, 18, 19

20, 21, 22

23, 24, 25

Illustrating the Emission of Light by the Edges of Apertures with Rectilinear Boundaries

On the Diffraction of Light by Cylinders of Large Radius (illustrated)—by Nalini Mohun Basu, M.Sc.

(See Proceedings, vol. III, Pt. 3).

On a Modification of Van Der Waal's Equation of State—by Meghnath Saha, M.Sc., and Satyendra Nath Bose, M.Sc.

(See Philosophical Magazine, July 1918).

On the Flow of Energy in the Electro-Magnetic Field surrounding a perfectly Reflecting Cylinder (illustrated)—by T. K. Chinmayanandam, B.A.

(See Proceediugs, vol. III, Pt. 5.)

On the Asymmetry of the Illumination-curves in Oblique Diffraction—by Sisir Kumar Mitra, M.Sc.

(See Philosophical Magazine, January 1918).

Parallax in Hindu Astronomy.

By Probodh Chandra Sen Gupta.

§ 1. *Introductory Investigation.*

Parallax is considered in Hindu Astronomy principally in connection with the calculation of a solar eclipse. The only other place where we meet with it is in the Goladhyaya of the Siddhanta Siromani, chapter VII, stanza 38, where Bhaskara recommends that the calculated altitude of a planet should be corrected for parallax in order to find the length of the shadow of the gnomon. It does not seem clear that the correction for parallax was ever made by any Hindu Astronomer in ordinary observations. In the calculation of a solar eclipse however, it could no longer be ignored, when it was discovered that the magnitude and the general character of a solar eclipse vary with the position of the observer and this variation is due to a difference between the parallaxes of the moon and the sun. The Siddhantas give us the correct rules for calculating this difference both in longitude and latitude at the instant of the new moon. In the solution of this problem the Hindu Astronomer starts with the hypothesis that the moon's latitude is zero, such as it approximately becomes at the time of an eclipse and obtains his expressions for the difference of parallax in longitude and latitude. With help of the former he finds the instant of conjunction as seen from the place of an observer and with the latter he corrects the latitude of the moon. He takes

this instant of conjunction for the middle of the solar eclipse and proceeds with the calculation of the different circumstances of it with respect to the observer.

The effect of parallax on the longitude and latitude of a planet is not given in ordinary text books on Astronomy and we think it convenient to give the following investigation for the sake of reference. Let P Z H (Fig. 1) be the observer's meridian; A C N, the ecliptic; M, the position of the planet; M′ the position as depressed by parallax; K, the pole of the ecliptic. Join K Z by an arc of a great circle cutting the ecliptic at N which will be the nonagesimal. Join K M, KM′ by arcs of great circles cutting the ecliptic at C and B. From M′ draw M′ Q′ perp. to K M C; then C B represents the parallax in longitude and M Q′ the parallax in latitude.

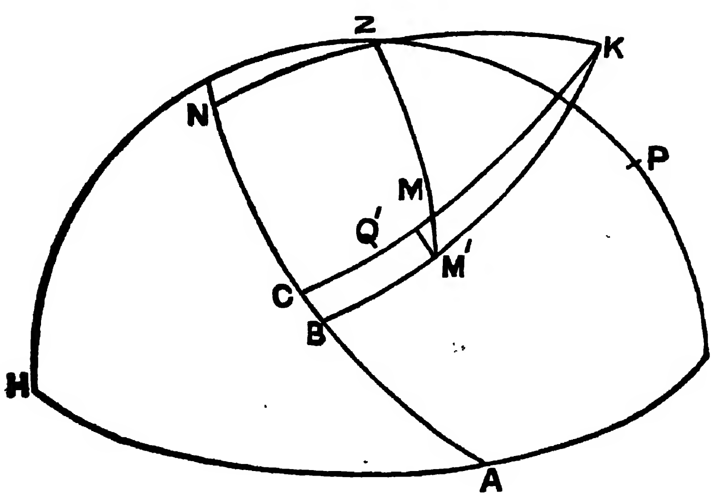


Fig. I.

Let Z denote Z M the zenith distance of the planet

l....................the longitude of M ;

λ....................the latitude ,, ,,

N....................the longitude of the nonagesimal,

Z'.................α.the zenith distance of the ,, ,, ,, .

Now $CB = \dfrac{M'Q'}{\text{Cos } M'B} = \dfrac{MM' \sin KMZ}{\text{Cos } M'B}$,

$= \dfrac{\pi \sin ZM \times \sin KMZ}{\text{Cos } M'B}$ ($\because MM' = \pi \sin ZM$, where π is the horizontal parallax of the planet),

$= \dfrac{\pi \sin ZM \times \sin ZK \times \sin ZKM}{\text{Sin } ZM \times \cos M'B}$ (from the triangle MKZ),

$= \dfrac{\pi \sin ZK \sin ZKM}{\text{Cos } M'B}$.

If α denotes the parallax in longititude, we have

$$\alpha = \frac{\pi \cos Z' \sin (l-N)}{\text{Cos } \lambda}. \quad \ldots \quad \ldots \quad \text{(A)}$$

When $\lambda = o$, the above is reduced to

$$\alpha = \pi \text{Cos } Z' \sin (l-N) \quad \ldots \quad \ldots \quad (1)$$

which is exactly the equation given in the Siddhantas.

Again $MQ' = MM' \cos KMZ$

$$= \pi \sin ZM \times \frac{\cos KZ - \cos KM \cos MZ}{\text{Sin } KM \sin MZ},$$

or $$\beta = \frac{\pi}{\text{Cos } \lambda}(\text{Sin } Z' - \sin \lambda \cos Z) \quad \ldots \quad \text{(B)}$$

where β stands for the parallax in latitude.

When $\lambda = o$, the above equation is reduced to

$\beta = \pi \sin Z'$, and this is the equation given in the Siddhantas. ... ... (2)

As the Surya Siddhanta is content with giving the rules only for the parallax in latitude and longitude, we have to turn to Bhaskara for the complete treatment of the subject.

§ 2. *Bhaskara's Treatment of Parallax in Longitude.*

The subject is treated in two places by Bhaskara (1) in the Grahaganita, chapter XII. and (2) in the Goladhyaya, chapter VIII. We begin with that given in the Grahaganita.

(1) "At the instant of conjunction of the sun and moon, although they may have the same longitude and latitude, an observer raised as he is from the centre of the earth by a distance equal to the radius, can not see them in the same line because they are at different distances from the earth. I shall therefore, here speak of both parallax in longitude and parallax in latitude."*

(2) "Find the longitude of the ascending point of the ecliptic and substract 3 signs (i.e. 90 degrees) from it in order to have the longitude of the nonagesimal If the sun be at the nonagesimal, there is no parallax in longitude; it is positive or negative according as the sun's longitude is in defect from or in excess of that of the nonagesimal."†

The above two passages are the texts and we have to turn to the commentary for the demonstration.

"Proof:—Let us call that circle to be the horizon which bisects the meridian, the prime vertical and the N. E. and S. E. verticals. When a planet is on this

---

* (1) दर्शान्तकालेऽपि समौ रवीन्दू द्रष्टा नतौ येन विभिन्नकक्षौ ।
कुर्ध्वस्थितः पश्यति नैकसूत्रे तल्लम्बनं तेन नतिं च वच्मि ॥

Grahaganita, Chapter XIII, Stanza 1.

† (2) दर्शान्तलग्नं प्रथमं विधाय नतलग्नं वित्रिभलग्नतुल्ये ।
रवौ तदूनेऽभ्यधिके च तत्स्यादेवं धनर्णं क्रमतश्च वेद्यम् ॥

Grahaganita, Chapter XIII, Stanza 2.

(rational) horizon an observer at the centre of the earth sees it horizontal. But the observer on the surface can not even see that (rational) horizon (through the planet); he considers another circle to be his horizon which is raised above the (rational) horizon in every direction by a height equal to the radius of the earth. As he sees the rest of the celestial sphere above it, he can not see the (rational) horizon which is depressed from his line of vision; hence at the orbit of the planet and in the vertical circle, the minutes of angle arising from the radius of earth are the minutes of angle convered by the earth; these are the min. of angle in the max. parallax in longitude and also those in the max. parallax in latitude. They are equal to $\frac{1}{15}$ of mean daily motion of the planet, as the radius of the earth is $\frac{1}{15}$ of the mean daily speed of all planets. (According to Hindu Astronomy all planets move towards the east round the earth with the same speed, the difference in their mean angular motions arising from the difference in distances from the earth. Now let r represent the radius of the earth and d the distance of the planet from the centre of the earth; hence in min. of arc

$\pi = \frac{r \times R}{d}$, where $R = 3438$ min. which is the same as the measure of 1 radian.

If ω be the mean daily angular motion of a planet in minutes, then

$\omega = \frac{s \times R}{d}$, where s denotes the common linear speed of all the planets. We have further $r = \frac{s}{15}$.

$$\pi = \frac{r \times R}{d} = \frac{s}{15} \times \frac{\omega}{s} = \frac{\omega}{15} \Big).$$

"When the planet is on the (rational) horizon, it is depressed by the minutes of angle covered by the earth. When the sun is at the zenith, the observer whether at the centre of the earth or on the surface, sees him at the zenith. As there is no depression in any direction there is no correction for parallax. On the horizon however parallax has the max. value equal to the min. of arc covered by the earth. It is thus seen that parallax arises when the sun is not at the zenith. Similar is the parallax of the moon. At the instant of conjunction the max. difference of parallax of the moon from that of sun, which is equal to the depression of the moon from the sun, is equal to the remainder of $48'.46''$. obtained by subtracting the parallax of the sun from that of the moon $\{i.e. = \frac{1}{15}(13^\circ.10'.35''.—0^\circ.59'.8'')\}$. When the ecliptic is vertical we employ the following proportion to convert this max. difference of parallaxes into *Ghatis* (*i.e.* $\frac{1}{60}$ of a day) of time: if the difference of mean daily motion is produced in the 60 *Ghati's* of one day; in what time is one fifteenth of the difference produced? The result is four *Ghatis* which is the max. difference of parallax in time. Hence it is clear that when the ecliptic is vertical, the difference of parallax should be found by a proportion to these four *Ghati's*. But when the ecliptic is inclined to the horizon, it is then found by two proportions.

Parallax certainly arises in a vertical circle, this is called *Madhyama*, which becomes the hypotenuse and projected towards the east of the ecliptic, becomes the parallax in longitude. When the ecliptic is vertical, the *Madhyama* parallax itself becomes the parallax in

longitude. * * * * * *

Thus as the lowest point of the ecliptic the parallax in longitude attains the maximum value and at the highest point there is no parallax. This highest point is at the nonagesimal. When the nonagesimal is at the zenith, the *jya* of its altitude (R cos Z′) is equal to the radius (R), the *Madhyama* parallax (*i.e.* in a vertical circle) becomes the parallax in longitude. When that nonagesimal is in-clined from the zenith, the *jya* of its altitude becomes less than the radius, the parallax in longitude becomes less than the parallax in the vertical circle, as the former is the base and the latter the hypotenuse of a (rt. angled) triangle. It is thus seen that parallax in longitude decreases with *jya* of the altitude of the nonagesimal. Hence it is necessary to take the proportion of the *jya* of the altitude of the nonagesimal, to find the parallax in longitude from the parallax in the vertical circle."

Having thus determined the method, Bhaskara gives rules for finding the parallax in longitude by using the two proportions.

(1) "Take the nonagesimal for the sun; find the part of its day elapsed, which is equal to the time of local rising of arc between the horoscope (लग्न) and the nonagesimal; next by calculating the ascentional difference, *antya* &c. determine the *jya* (R cos Z′) and *kojya* (R sin Z′) of the altitude of the nonagesimal."

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(1) त्रिभोनलग्नांतरपि प्रकल्प्य तल्लग्नयोर्यैः समयोऽन्तरेऽसौ ।
त्रिभोनलग्नस्य भवेद्द्युयातः पलाद्यतस्तस्य चरान्त्यकाद्यैः ॥

(2) "Take the *jya* of the arc between the nonagesimal and the sun, multiply it by four and divide by the radius (3438); multiply the quotient thus obtained by the *jya* of the altitude of the nonagesimal and divide by the radius; the result is the parallax in longitude in *Ghatis* of time."

$$\left\{\text{Symbolically } \alpha = \frac{4 \times \mathrm{R} \sin (l-\mathrm{N})}{\mathrm{R}} \times \frac{\mathrm{R} \cos \mathrm{Z}'}{\mathrm{R}}\right\}$$

It is thus seen that the rule gives same relation as (1) obtained in the introductory investigation. In the proof Bhaskara first assumes the ecliptic to be vertical and determines the Madhymama parallax by the proportion: if for a *jya* equal to the radius of the arc between the sun and the nonagesimal, four *ghatis* be the parallax in time, what is the parallax for the *jya* determined? The result is Madhyama parallax. He next employs a second proportion to convert it into

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(2) त्रिभोनलग्नार्कविशेषशिञ्जिनी कृताहताव्यासदलेनभाजिता ।
हतात्फलाद्दृक्त्रिभलग्नशङ्कुना त्रिजीवयाप्तंघटिकादिलम्बनम् ॥

Grahaganita, Chapter XII, Stanzas 3 & 4.

NOTE.—Evidently these rules were taken from Brahmagupta's work, the corresponding stanzas from which are:—

वित्रिभलग्नसमेऽर्के न लम्बनं तदधिकोनके भवति ।
तत्क्रान्तिज्योदक् यदाक्ष जीवा समा न तदा ॥
अवनतिरतोऽन्यथा भवति सम्भवे तदुदयैर्विलग्नसमम् ।
लग्नात्तदुदित घटिकास्त छङ्कुस्तंभर प्राणैः ॥
त्रिज्याहतेचतुर्गुणशङ्कुहृतायाः फलेन भक्तायाः ।
तात्कालिकार्कत्रिभयोन लग्नान्तरज्यायाः ॥
लम्बनघटिकालब्धं लग्नात् तात्कालिकात् त्रिराशिगात् ।
ऊनमधिकेऽर्के हीने धनमसकृत्पश्चदृश्यन्ते ॥

Brahma-Sphuta-Siddhanta, Chapter V, stanzas 2—5.

parallax in longitude : if for a *jya* equal to the radius of the altitude of the nonagesimal, this be the parallax, what is the parallax for any given *jya* of the altitude of the nonagesimal ? Here the parallax in longitude varies as the *jya* of the arc of the ecliptic between the sun and the nonagesimal when the *jya* of the altitude of the nonagesimal remains equal to the radius ; again it varies as the *jya* of the altitude of the nonagesimal when the *jya* of the arc between the nonagesimal and the sun remains equal to the radius. Bhaskara seems to employ the well known principle of variation or double rule of three in obtaining his equation. The way in which he arrives at the conclusion that parallax in longitude varies with the *jya* of the alt. of the nonagesimal is to be considered as a rather bold one ; it seems to us to be a shrewd guess.

The above extract may be translated as follows :—

"There is no parallax in longitude when the longitudes of the sun and the nonagesimal are equal and it occurs when the longitude of the sun is in excess of or in defect from that of the nonagesimal. Similarly there is no parallax in latitude when the *jya* of the north declination of the nonagesimal equals the *jya* of the latitude of the station, and it arises in other situations. When the parallax in longitude is possible, take the nonagesimal for the sun and by means of the times of local risings of the sign of the zodiac, determine the number of *Ghatikas* ($\frac{1}{60}$ of a day) by which it has risen above the horizon ; next determine the *jya* of the altitude of the nonagesimal with the help its minutes of ascensional difference (चर). Divide the square of the radius by four times the *jya* of the alt. of the nonagesimal ; by the quotient obtained divide the *jya* of the arc bet. the sun and the nonagesimal ; the result expresses the parallax in longitude in *Ghatis* of time. This is applied negatively or positively to the instant of conjunction as the longitude of the sun is greater or less than that of the nonagesimal."

§ 3. *The rule of the Suryasiddhanta.*

The S. Siddhanta also gives the same rule, only the terminology is slightly different.

(1) "Divide the square of the *jya* of one sign $\left(i.e.\ \mathrm{R} \sin 30 = \frac{\mathrm{R}}{2}\right)$ by the ko-*jya* of the zenith distance of the nonagesimal, let the quotient be called ***chheda***. Find the *jya* of the arc of the ecliptic between the nonagesimal and the sun, divide it by the ***chheda***, the result is the difference of parallax in longitude of the moon from sun, expressed in ***ghatis***."

$$\left\{ \text{Symbolically, chheda} = \frac{\left(\frac{\mathrm{R}}{2}\right)^2}{\mathrm{R} \cos Z'} \text{ and} \right.$$

$$\left. \alpha = \frac{\mathrm{R} \sin (l - \mathrm{N})}{\frac{\mathrm{R}^2}{4\, \mathrm{R} \cos Z'}} = \frac{4 \times \mathrm{R} \sin (l - \mathrm{N}) \times \mathrm{R} \cos Z'}{\mathrm{R}^2} \right\}.$$

It is evident that the rule of the Surya Siddhanta is the same as that of Bhaskara. It is further clear that the *Ghatis* of parallax in longitude of the moon from the sun, applied to the time of conjunction, gives the time of conjunction as seen by the observer on the surface of the earth.

§ 4. *Treatment of parallax in the Goladhyaya.*

We have seen that Bhaskara's treatment of parallax in the Grahaganita is not very good from the point of view of theory and his treatment of the difference of

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(1) एकज्या वर्गतश्छेदो लब्धं दृग्गतिजीवया ॥
मध्यलग्नार्क विश्लेषज्याच्छेदेन विभाजिता ।
रवीन्द्वोर्लम्बनं ज्ञेयं * * * * ॥

S. Siddhantha, Chapter. V.

parallax in latitude as considered there will also be found to be not very satisfactory. In the Goladhyaya however he gives a complete exposition of the subject in a very neat manner.

(1) "As the observer, raised as he is from the centre by a distance equal to the radius of the earth sees the moon depressed from her position as seen from the centre, the parallaxes in longitude and in latitude are found from the radius of the earth. The subject may be made clear to the beginner diagrammatically as follows :—Let the earth and the orbits of the sun and the moon, be drawn on a wall according to a suitable scale. Through the centre of the diagram (i.e. of the earth) let a horizontal line and a vertical line be drawn. Let the point of intersection of the horizontal line with each orbit be taken for the horizon in each; and that with the vertical line, for the zenith.

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(1) यतः कर्धोच्छ्रितो द्रष्टा चन्द्रं पश्यति लम्बितम् ।
साध्यते कुदलेनातो लम्बनं च नतिस्तथा ॥
द्रष्टापवर्त्तितां पृथ्वीं कक्षे च शशिसूर्य्ययोः ।
भित्तौ विलिख्य तन्मध्ये तिर्य्यग्रेखां तथोर्द्ध्वगाम् ॥
तिर्य्यग्रेखायुतौ कल्प्यं कक्षायां क्षितिजं तथा ।
ऊर्द्ध्वरेखायुतौ खाङ्कं दृग्ज्या चापांशकैर्नतौ ॥
कृत्वार्केन्दू समुत्पत्तिं लम्बनस्य प्रदर्शयेत् ।
एकं भूमध्यतः सूत्रं नयेच्चण्डांशुमण्डलम् ॥
द्रष्टुर्भूपृष्ठगादन्यद् दृष्टिसूत्रं तदुच्यते ।
कक्षायां सूत्रयोर्मध्ये यास्ता लम्बनलिप्तिकाः ॥
गर्भसूत्रे सदाख्यातौ चन्द्रार्कौ समलिप्तिकौ ।
दृक्सूत्राल्लम्बितश्चन्द्रस्तेन तल्लम्बनं स्फुटम् ॥
दृग्गर्भसूत्रयोरैक्यात्खमध्ये नास्तिलम्बनम् ।

Goldhyaya, Chapter VIII. Stanzas 11—16.

Now let the positions of the sun and the moon be marked off in each orbit by marking off the degrees of angle in their common zenith distance (since it is supposed that at the instant of conjunction the latitude of the moon is nil), and the way in which a parallactic depression of the moon from the sun arises, should then be demonstrated in the following manner: let a straight line be drawn from the centre of the earth to the sun (which will of course pass through the moon), let there be drawn also the straight line from the observer on the surface to the sun; the number of minutes formed by the straight lines at the orbit represents the parallax of the sun. At the instant of conjunction (when the latitude of the moon is nil) the moon and the sun will be in the line joining the sun with the centre of the earth; and the moon is seen depressed from the direction of the sun by the observer on the surface, and hence this is called depression (i.e. difference of parallax). There is no depression when the zenith distance is nil, as in that case the lines joining the sun to the observer and the centre of the earth, coincide.

Having thus spoken of the parallax in the vertical circle Braskara proceeds to explain the difference of parallax of the moon from the sun in latitude, in the following manner:

(1) "Let a diagram be drawn as before on a wall running north and south and let the orbits drawn be taken for the vertical circles through the nonagesimals.

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(1) अथ याम्योत्तरायां तु भित्तौ पूर्ववदालिखेत् ॥
ये कक्षावृत्ते तत्रैव दृक्क्षेपवृत्ते ।
• • • दृक्क्षेपो • • ।

* * * * In each circle let a point be marked from the zenith by means of the degrees of angle in the zenith distance of nonagesimal and let the points be taken as the two nonagesimals. In this figure the depression of the lunar nonagesimal from the solar nonagesimal formed as before is known as the difference of parallax in latitude or *Nati.* As the angular depression (perpendicular to the ecliptic) of every point of the lunar orbit from the corresponding point of the ecliptic is everywhere the same as that at the nonagesimal, the difference of parallax in latitude is found from the *jya* of the zenith distance of the nonagesimal."

Bhaskara here assumes for the sake of simplicity that the orbits of the moon and the sun are co-planar, yet how ingeniously does he find the parallax in latitude for any point of the lunar orbit! He next proceeds to define the parallax in longitude and shows its relation to the parallax in the vertical circle and the parallax in latitude.

(2) "When the sun is any way inclined from the zenith, the moon is depressed from him downwards; this depression takes place in the vertical circle and

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तत्रापांशैर्नतौ बिन्दू कृत्वा वित्रिभसंज्ञकौ ।
तद्व्यवधिकलाः प्राग्वद्दृक्क्षेपाख्या नतिर्लिप्तिकाः ॥
कक्षयोरन्तरं यत्स्याद्दृग्वित्रिभे सर्वतोऽपि तत् ।
याम्योत्तरं नतिः साऽत्र दृक्क्षेपात् साध्यते ततः ।

Goladhyaya, Chapter VIII. Stanzas 17 to 20.

(2) यत्र यत्र नताद्दृश्यर्काद् अधश्चन्द्रावलम्बनम् ।
तद्दृग्वृत्तेऽन्तरं चन्द्रभान्वोः पूर्वापरं तु तत् ॥
पूर्वापरं च याम्योदग् जातं तेनान्तरद्वयम् ।
कक्षापमण्डलं प्राची तत्तिर्यक् दक्षिणोत्तरा ॥

may be called east or west of that circle. Owing to this there arises two differences, one of which is east or west, while the other is north and south. Here along the ecliptic (in the same direction as the signs of the zodiac) is the east and perpendicular to it is the north-south direction. The difference which is either in the east or west direction is *Sphuta Lambana* or difference of parallax in longitude, while the difference which is either in the north or south direction is called *Nati* or difference of parallax in latitude. In the triangle of parallax, *Nàti* is the perpendicular, the difference of parallax in the vertical the hypotenuse and the base which is the *Sphuta Lambana* is equal to the square root of the difference of their squares."

(1) "The difference of horizontal parallax of the moon from that of the sun, multiplied by the *jya* of the sun's zenith distance, is the difference of parallax in the vertical circle. $\left\{(\pi_m - \pi_s) \times \frac{R \sin Z}{R}\right\}$. In the same way the difference of parallax in latitude is obtained from the *jya* of the zenith distance of the

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यत् पूर्वापरभावेन लम्बनाख्यं तदान्तरम् ।
यद्दक्षिणोत्तरभावेन नति संज्ञं तदुच्यते ॥
नतिर्लिप्ताभुजः कर्णो दृग्लम्बन कलास्तयो ।
कृत्यन्तर पदं कोटिःस्फुटलम्बनलिप्तिका: ॥

Ibid. Stanzas 21—24.

(1) परलम्बन विप्ताप्तोर्निघ्नाप्ता रविदृग्ज्यका ।
दृग्लम्बनकलास्ता: स्युरेवं दृक्क्षेपतोनति ॥

Goladhyaya, Chapter VIII. Stanza 25.

nonagesimal". $\left\{i.e.\ (\pi_m-\pi_s)\times\frac{R\sin Z'}{R}=\text{Nati}, Z'\right.$ being the zenith distance of the nonagesimal.$\}$*

* NOTE.—In Fig. II, let PZH be the observer's meridian; HEA, the horizon; AQN, the ecliptic; N, the nonagesimal: S, the sun on the ecliptic; S', his position as depressed by parallax; then SQ represents the parallax in longitude and S'Q the parallax in latitude.

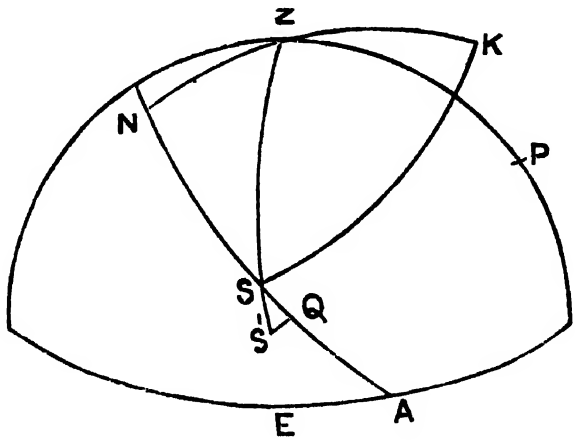

Fig. II.

If SS' be taken to be depression of the moon from the sun, then

$$SS'=(\pi_m-\pi_s)\times\frac{R\sin Z}{R}=(\pi_m-\pi_s)\times\frac{R\sin ZS}{R}\ \text{and}$$

$$S'Q=(\pi_m-\pi_s)\times\frac{R\sin Z'}{R}=(\pi_m-\pi_s)\times\frac{R\sin ZN}{R}.$$

$\therefore$ SQ = the parallax in longitude,

$$=(\pi_m-\pi_s)\times\frac{1}{R}\times\sqrt{R^2\sin^2 ZS-R^2\sin^2 ZN}\ . \qquad \dots \quad (1)$$

But $\sqrt{R^2\sin^2 ZS-R^2\sin^2 ZN}=$ *jya* of ZKS in the small circle through Z parallel to the ecliptic,

$$=\frac{R\sin NS}{R}\times R\cos ZN.$$

The parallax in longitude $=(\pi_m-\pi_s)\times\frac{1}{R}\times\frac{R\sin NS}{R}\times R\cos ZN$

$$=(\pi_m-\pi_s)\,\frac{R\sin(l-N)\times R\cos Z'}{R^2} \qquad (2)$$

(2) "One fifteenth of the difference of the daily angular motions is the difference of horizontal parallax, viz , 48.′ 46 ;″ because the radius of the earth is equal to one fifteenth of the mean linear speed of a planet. The Sphuta Lambana or the difference of parallax in longitude expressed in minutes being divided by the degrees in the difference of angular motions becomes the *Sphuta Lambana* expressed in *Ghatis.* On the east (of the nonagesimal) the moon is depressed ahead

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The expression under the radical sign is also easily reduced to the form in (2) by using the right angled triangle ZNS. In the form (1), the equation occurs in the Surya Siddhanta as known to Varahamitira, in the Sishya Dhibriddhida of Lalla, in Brahma Gupta and Bhaskara (vide Pancha Siddhantika, Chapter IX, stanzas 19—22 ; Sishya Dhibriddhida Chapter V, stanzas 4—6 ; Brahmagupta, Chapter XI, stanza 23). In the second form we find it in the modern Surya Siddhanta, Brahmagupta and Bhaskara. If we suppose, that the modern Surya Siddhanta is a later production than the Brahma Sphuta Siddhanta, the credit of reducing (1) to the form (2) belongs to Brahmagupta. As to the method of calculating the zenith distance of the nonagesimal, the Arya-Bhatiya, Sishya Dhibriddhida, the old and the modern S. Siddhantas fall in one class, to the other class belong Brahmagupta and Bhaskara ; the rules given by the former are only approximate, while those of the latter are accurate.

(2) गत्यन्तरस्य तिथ्यंशः परलम्बनलिप्तिकाः ।
गतियोजन तिथ्यंशः कुदलस्य यतोमितिः ॥
स्फुटलम्बनकला नाड्यो गत्यन्तरलवोद्धृताः ।
प्रागग्रतो रवेश्चन्द्रः पश्चात् पृष्ठेऽवलम्बितः ॥
प्रोञ्चेऽग्रे द्युतिर्याता गम्या पृष्ठगते यतः ।
प्राक्स्थं तद्धनं पश्चात् क्रियते लम्बनं तिथौ ॥
याम्योत्तरं परस्तावद् अन्तरं शशि सूर्य्ययोः ।
नतिस्तथा तथा नत्यात् संस्कृतः स्यात् स्फुटः शरः ॥

Goladhyaya, Chapter VIII. Stanzas 26—29.

of the sun and on the west, behind the sun. As the conjunction is to be considered as over when the quicker planet (i.e. the moon) is ahead of the sun, and is to be considered as yet to take place, when the quicker planet is behind the sun, it follows that the difference of parallax expressed in *Ghatis* is to be applied to the instant of conjunction, negatively on the east and positively on the west. The latitude of the moon is her distance from the sun and is north-south, so is also the *Nati*; hence the latter applied to the former gives the *Sphuta* latitude or the apparent distance of the moon from the sun as seen from the surface."

The expression for the difference of parallax in latitude as obtained by Bhaskara also coincides exactly with that of the introductory investigation. The Surya Siddhanta also gives the same rule in chapter V. stanza 10.

§ 5. *Conclusion.*

The above is a fairly complete account of the treatment of parallax as given by Bhaskara and he has no originality here. Hence it may be regarded as the representative account of the way in which the problem was attacked by the ancient Hindu Astronomers. It will be seen that the sun's harizontal parallax according to Hindu Astronomy is$=\frac{1}{15}$ of $59.' \, 8''=3.' \, 56.''5$, whereas its value as now determined$=9''$ nearly; while that of the moon$=\frac{1}{15}$ of $13.^\circ \, 10.' \, 35''=52.' \, 6''.3$ according to Hindu Astronomers and the accurate value$=58.'' \, 1.''$

It is thus evident that both the quantities are far inaccurate. Further from the theory of mean motion

as explained in the above account, it appears that the Hindu Astronomers took the mean distances of the sun and the moon to be in the inverse ratio of their mean daily motion, i.e. as 13 : 1 nearly. Although the constants used were all inaccurate, and the circumstances of a solar eclipse calculated from these data were necessarity all at variance with observation, yet the way in which they handled the subject deserves ample praise. Although it must be admitted that they did not attempt to find expressions for parallax in longitude and latitude generally, the ones they obtained were quite sufficient for the time of a solar eclipse and their way of obtaining the expression for the parallax in latitude is indeed very elegant.

On Sommerfeld's Treatment of the Problem of Diffraction by a Semi-infinite Screen.

By

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§ 1. *Introduction.*

The rigorous treatment of the effect of obstacles on the propagation of light, considered as a boundary value problem in analysis, has received much attention from mathematical physicists during recent years.* The particular case of the diffraction of light by a semi-infinite perfectly reflecting screen for which the complete solution was first given by Sommerfeld† (and later also by Carslaw‡) has been more recently dealt with by Lamb§ in a paper characterised by very simple and elegant mathematical analysis. As remarked by Lamb in his paper, the principal interest to the physicist of investigations such as these, lies in the fact that they afford a check on the accuracy of the results obtained by less rigorous mathematical methods, and also enable a comparison of the theory with experi-

* An excellent summary of the literature on the subject with references to the original papers will be found in the article by Epstein in the Encyclo. Math. Wiss (Section on Wave Optics, 1914.)

† Sommerfeld Math. Annalen, t. XLVII, page 317 (1895).

‡ Carslaw, Proc. Lond. Math. Soc., t. XXX, page 121 (1899).

§ Lamb, Proc Lond. Math. Soc., (2) t. IV, page 190 (1906).

ment to be carried out for cases in which the ordinary treatment can hardly be regarded as applicable. A comparison of the results of the approximate theory with those deduced from the rigorous analysis for the case of the semi-infinite screen has been made by Sommerfeld himself, and also by Drude* who has used the Cornu spirals with good effect, in his discussion of the value of Sommerfeld's integrals. According to these writers, Kirchhoff's formula should give the value of the intensity of illumination with sufficient accuracy when the angle of diffraction is small, that is, at all points of the field (except very near the edge of the screen) which are not far removed from the boundary between light and shadow; but for large angles of diffraction, Kirchhoff's formula is inapplicable. It appears, however, from a careful examination of the formulæ given by Sommerfeld and Drude that the statement made by them on this point requries to be qualified in one important respect. I propose in the present paper to show by a detailed discussion that *when the screen is held very obliquely in the path of the incident waves*, the rigorous treatment gives results differing from those of the approximate theory *even in regard to small angles of diffraction.* Experimental work recently carried out by me and described in the course of the paper confirms this, and shows that the approximate theory of diffraction fails to represent the facts correctly under these conditions. Incidentally it is found, that in the case of light polarised in a plane perpendicular to that

* Drude Theory of Optics. English translation by Mann and Millikan (1902) page 203.

of incidence, the boundary condition at the screen assumed by Sommerfeld leads to results differing very widely from the observed optical behaviour of any actual screen at very oblique incidences, and a suggestion is made as to the manner in which the rigorous solution should be modified in order to secure an agreement with the results obtained experimentally in this case.

§ 2. *Theory*.

It is convenient here to state Sommerfeld's results in the simplified form obtained by him from a semi-convergent expansion of the integrals representing the complete solution.

This is

$$S=\cos\left[\frac{2\pi}{\lambda}r\cos(\phi-\phi')+nt\right]\mp\cos\left[\frac{2\pi}{\lambda}\cos(\phi+\phi')+nt\right]$$

$$+\frac{1}{4\pi}\sqrt{\frac{\lambda}{r}}\left[\pm\frac{1}{\cos\frac{\phi+\phi'}{2}}-\frac{1}{\cos\frac{\phi-\phi'}{2}}\right]\cos\left[\frac{2\pi}{\lambda}r+\frac{\pi}{4}-nt\right]$$

where S is the light disturbance, ϕ' and ϕ are respectively the angles made by the incident rays and by the radius vector with the plane of the screen, and r is the distance of the point of observation from the edge of the screen. The alternative signs refer to the state of polarisation of the incident light. The upper sign should be taken in the case when the incident light is polarised in a plane perpendicular to the edge of the screen, *i.e.*, when the electric vector is parallel to the edge, and the lower sign in the case when the light is polarised in a plane parallel to

the edge, *i.e.*, when the magnetic vector is parallel to the edge. The first and second terms in the expression represent the incident and the reflected waves respectively, while the third term gives the wave of diffraction. In the region of shadow, only the third term should be taken into account; in the region of transmission we have to take the first and third terms only, while in the region of reflexion all the three terms in the expression for the light disturbance have to be retained. Thus beyond the path of the rays determined by geometrical optics, there is a wave of diffraction whose phase is determined by the factor

$$\cos\left[\frac{2\pi}{\lambda}r+\frac{\pi}{4}-nt\right]$$

and whose amplitude by the factor

$$\frac{1}{4\pi}\sqrt{\frac{\lambda}{r}}\left[\pm\frac{1}{\cos\frac{\phi+\phi'}{2}}-\frac{1}{\cos\frac{\phi-\phi'}{2}}\right]\cos\left[\frac{2\lambda}{\pi}r+\frac{\pi}{4}-nt\right]$$

The lines of equal phase are circles round the point $r=o$, so that from this point rays start out in all sides in the direction of the radius vector straight on as if the edge of the screen were a linear source of light. The intensity of these cylindical waves is however not same in all directions. It is greatest near the region of the two boundaries separating the different parts of the field and gradually diminishes as we go away from these boundaries.

As is well known, the most remarkable result indicated by Sommerfeld's analysis and which is in substantial agreemet with the experimental observations of Gouy, Wien and others, is that the amplitude of the

diffracted waves is different for light polarised in and at right angles to the plane of incidence. This is sufficiently clear from the expression given above. For small angles of diffraction however, that is in the neighbourhood of the planes defined by $\phi=\pi-\phi'$ and $\phi=\pi+\phi'$, the difference in the magnitudes of the two components is generally, quite negligible. For, in the neighbourhood of the first plane, $\dfrac{1}{\cos\dfrac{\phi+\phi'}{2}}$ in numerically very large compared with $\dfrac{1}{\dfrac{\phi-\phi'}{}}$ and similarly in the neighbourhood of the second plane, $\dfrac{1}{\cos\dfrac{\phi-\phi'}{2}}$, is very large compared with $\dfrac{1}{\dfrac{\phi+\phi'}{2}}$. Accordingly, in the neighbourhood of these two planes, it is ordinarily sufficient to retain one of the two terms and neglect the other in the expression for the amplitude of the diffracted waves, which is thus numerically the same for both states of polarisation, and for the region considered is in substantial agreement with that found from the approximate theory. But the preceeding argument fails entirely when ϕ' is nearly equal either to π or zero, that is when the incidence of the light at the secreen is very oblique: For the two terms $\dfrac{1}{\cos\dfrac{\phi+\phi'}{2}}$ and $\dfrac{1}{\cos\dfrac{\phi-\phi'}{2}}$ are then always of comparable magnitude, and have both to be retained. It is thus clear that some special features

are to be expected when the incidence of light on the screen is very oblique.

We may now consider separately the two cases in which ϕ' is nearly equal to π and zero respectively, as they present distinctive features. When ϕ' is nearly equal to π (see Fig 1.a and 1.b), by far the largest part of the field is occupied by the region of transmission (marked II in the Fig.), and the remaining part of the field is equally divided between the regions of shadow and of reflexion (marked I and III respectively in the Fig.) which lie on opposite sides of the screen and are completely separated by it. If we wish to observe the phenomena in the neighbourhood of the boundaries separating the different parts of the field, we have two distinct choices open to us.

We may either study the phenomena near the boundary separating regions I and II where ϕ is nearly equal to 2π (Fig 1. a), or near the corresponding boundary on the other side of the screen between regions II and III in which case ϕ is nearly equal to zero. (Fig 1 b.) The case in which ϕ is nearly equal to 2π is the simpler of the two, as we are then concerned only with the transmitted and diffracted wave trains. Putting $\phi'=\pi-\alpha$ and $\phi=2\pi-\beta$ where α and β are small angles (fig 1. a) it is found that $\dfrac{1}{\cos\dfrac{\phi+\phi'}{2}}$ and $\dfrac{1}{\cos\dfrac{\phi-\phi'}{2}}$ are of comparable magnitude. Sommerfeld's formula thus leads to the striking result that in the case of a very obliquely held screen, the intensity of the diffraction fringes seen near the boundary between light and shadow should depend to a very considerable extend upon the

plane of polarisation of the incident light and should be quite different from that given by Kirchhoff's formula.

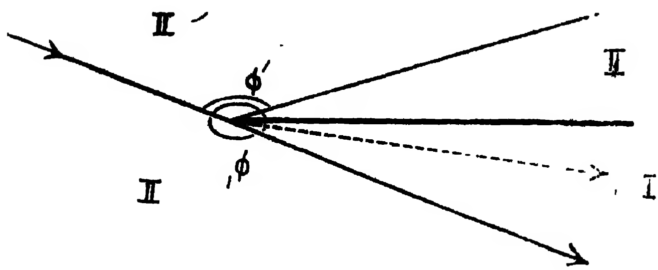


Fig. 1a.

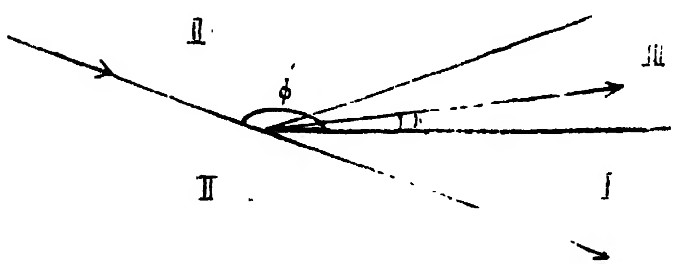


Fig. 1b.

Similarly on the other side the screen (Fig 1. b) putting $\phi'=\pi-\alpha$ and $\phi=\beta$ where α and β are small angles, we may work out the expression for the light disturbance. If $\beta > \alpha$ we are only concerned with the interference of the incident and diffracted wave trains, while if $\beta < \alpha$ we have to consider the stationary waves formed by the interference of incident and reflected wave trains as modified by the superposition of the cylindrical waves radiated by the edge of the screen. If the light be polarised in the plane of incidence, we find that when ϕ is vanishingly small, the expression

for the light disturbance is zero. This shows that the surface of the mirror is a nodal plane for the light vector in this case. On the other hand if the light be polarised perpendicular to the plane of incidence, it is found that for vanishingly small value of ϕ, that is, along the surface of the mirror, the intensity of the diffracted rays does *not* vanish and that, moreover, the incident and reflected wave trains re-inforce one another, the light vector being thus a maximum at the surface of the mirror. The last-mentioned result is a direct consequence of the boundary condition $\left(\frac{\partial s}{\partial z}=0\right)$ at the surface of the mirror assumed by Sommerfeld as the basis of his work, but is contrary to the observed optical behaviour of any actual screen at very oblique incidences. In practice any polished surface is at such incidences, mearly a perfect reflector, but as shown by Lloyd's experiment, both the electric and magnetic vectors in the incident and reflected waves are of opposite signs at the surface irrespective of the plane of polarisation of the incident light, and their resultant is zero.

The preceding discussion makes it clear that the solution obtained with the boundary condition $\frac{\partial s}{\partial z}=0$ for the light vector at the surface of the mirror is entirely inapplicable under experimental conditions for oblique incidences. The solution obtained with the boundary condition $(s=0)$ may however for our present purpose be regarded as practically valid at all incidences for any screen which is a sufficiently near approach to a perfect reflector, provided *the light be polarised in the*

plane of incidence. The experimental investigation described in the present paper shows that *the same solution may also be regarded as applicable for light polarised at right angles to the plane of incidence* provided the incidence be very oblique, and attention is confined to the phenomena observed at small angles of diffraction.

§ 3. *Experimental Method and Results.*

The diffraction fringes of the Fresnel type bordering the shadow of an obliquely held screen may be observed with the arrangement shown diagramatically in Fig 1. a. A front-silvered glass plate M bordered by parallel straight edges may be used as the screen. The first edge diffracts the incident light, and by observing the fringes near the surface of the mirror at the second edge, the necessity of using an infinitely extended screen is avoided. The contrast between the maxima and minima of illumination is found to be not entirely independent of the inclination of the surface of the screen to the direction of the incident rays. When the inclination is considerable, the fringes at the edge of the shadow are of course, of the usual Fresnel type, few in number and very diffuse. But as the surface is gradually brought up to the position in which it just begins to graze the incident light, the contrast between the maxima and minima of illumination in the fringes gradually increases, their relative positions remaining unaltered and at the same time the falling off of the intensity to zero inside the geometrical shadow of the screen becomes more rapid than in the diffraction fringes of the ordinary type due to a

normally held screen. On examination of the fringes through a nicol, it is found that the intensity of the fringes is independent of the plane of polarisation of the incident light.

A detailed comparison has been carried out between the position and the intensity of the fringes as observed experimentally with those calculated from the theoretical expression

$$S = \cos\left[\frac{2\pi}{\lambda} r \cos(\phi-\phi')+nt\right]$$
$$+ \frac{1}{4\pi}\sqrt{\frac{\lambda}{r}}\left[\frac{1}{\cos\frac{\phi+\phi'}{2}} - \frac{1}{\cos\frac{\phi-\phi'}{2}}\right]$$
$$\cos\left[\frac{2\pi}{\lambda} r + \frac{\pi}{4} - nt\right]$$

which satisfies the boundary condition $s=0$ at the surface of the mirror. When ϕ' in much less than π, the intensity curve given by the expression is practically the same as that obtained from usual Fresnel integrals and is shown in the dotted line in Plate I Fig 3 (*c*).* As ϕ' is gradually increased so as to approach the value π, the maxima and minima of illumination remain unaltered in position, but the contrast between them gradully increases. The full line in Plate I Fig 3 (*c*) shows the calculated intensity curve in the limiting case in which ϕ' is equal to π and the screen just grazes the incident light. The illumination is seen to be zero on the surface of the mirror.

* The asymptotic expansion given by Sommerfeld is inapplicable over a very small part of the field on either side of the boundaries $\phi=\pi+\phi'$ and $\pi-\phi'$. A small part of each of the curves shown in Fig. 3 was accordingly filled in in freehand so as to represent as closely as possible the general trend of the curve.

Table I shows in the first column the intensities of the maxima and minima in the diffraction fringes of the Fresnel type due to a normally-held screen and in the second column those due to a screen grazed by incident rays, the intensity in the incident waves being taken as unity. The positions of the minina are also given, which are of course the same in both cases.

TABLE I.

$\lambda = 4377 \times 10^{-8}$ cm, $r = 30{\cdot}75$ cm, $\phi' = 179^\circ\ 54'{\cdot}56$.

Calculated intensity at the [illegible] and [illegible]		Calculated intensity at the maxima and minima case II.		Calculated distances of the minima from the edge case I and II. $\times\sqrt{\frac{2}{r\lambda}}$ in cm	Observed distances of the minima from the edge in case II. $\times\sqrt{\frac{2}{r\lambda}}$ in cm
Max.	Min.	Max.	Min.		
1·37		1·95			
	·78		·58	1·871	1·853
1·20		1·41			
	·84		·69	2·739	2·714
1·15		1·30			
	·87		·76	3·391	3·340
1·12		1·28			
	·89		·79	3·937	3·930
1·11		1·22			
	·90		·80	4·416	4·393
1·10		1·19			
	·91		·81	4·848	4·830
1·09		1·18			
	·92		·82	5·244	5·216

The fourth column in the Table gives the positions of the maxima and minima of illumination measured on a photograph taken of the fringes due to a screen grazed by the incident rays, and these agree closely with the theoretical values given in the third column.

The ratios of the intensity of illumination at the maxima and minima have been determined photometrically for comparison with the theoretical value shown in the first column of Table I. As mentioned above, the intensities were found to be independent of the plane of polarisation of the incident light. The method adopted for the photometric work was as follows. The incident light was plane polarised by passage through a nicol. Two narrow slits were mounted one above the other in the plane of the diffraction fringes, and a thin plate of mica of proper thickness (·032mm) was fixed up on the upper one so oriented that it circularly polarised the light falling on it. The field was observed through an eyepiece and an analysing nicol mounted in a graduated circle. The lower and the upper slits were then respectively set on the 1st maximum and the 1st minimum, or the 2nd maximum and the 2nd minimum and so on. The illuminations of the upper and lower slits were equalised by rotating the analysing nicol, and the position of the analyser at which the light from the lower slit was extinguished was also noted. The angular difference of the two positions suffices to give the ratio of the illuminations. Thus if θ_1 and θ_2 be the two positions, and I_1 and I_2 the intensities of illumination of the upper and lower slit respectively,

$$\frac{I_1}{I_2} = \sin^2(\theta_1 - \theta_2)$$

A correction was made for the loss of light in transmission through the mica sheet covering the upper slit.

TABLE II.

Ratio of the intensities of Minima and Maxima.	Observed value.	Value Calculated from Sommerfeld's expression.	Value Calculated from Fresnel's integrals.
1st min. and 1st max.	·36	·30	·58
2nd min. and 2nd max.	·53	·50	·67
3rd min. and 3rd max.	·60	·57	·79

Table II shows the results of the photometic work which was carried out on the fringes obtained with monochromatic light. It was not found practicable to carry the measurement beyond the third fringe. The photograph reproduced in the Plate II Fig. 4 (c) clearly shows that the contrasts between the maxima and minima of illumination in this case are greater than in the diffraction fringes of the Fresnel type.

Two other cases besides that described above have been investigated experimentally. In one of these (shown diagramatically in Fig. 1. b) ϕ' was nearly equal to π and ϕ was small and positive. The positions and magnitudes of the maxima and minima of illumination calculated from Sommerfeld's solution (the upper sign only being taken) and the experimental data are shown in Table III for comparison. The illumination-curve for this case is shown in Plate I, Fig. 3 (b) and the photograph on which the measurements were made is reproduced in Plate II, Fig. 4 (b).

In this case on the side of the screen under observation, only the reflected wave-front is limited by a boundary passing through the edge of the screen and suffers diffraction, and the general agreement between theory and experiment is only rendered possible by taking for the former, the rigorous solution obtained by Sommerfeld, the boundary condition $s=0$ being assumed to be the satisfied at the surface of the screen.

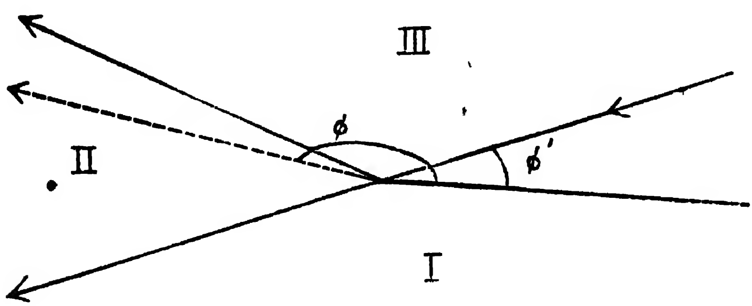
TABLE III.

$r=30{\cdot}75$ cm, $\lambda=4380\times10^{-8}$ cm.

Intensity at the Maxima and Minima.		Calculated position of the minima distance from the edge in cm.	Observed position of the minima distance from the edge in cm.
Max.	Min.		
4·0			
	·18	·0140	·0140
4·5			
	·02	·0278	·0275
3·6			
	·20	·0423	·0421
3·0			
	·21	·0558	·0554
2·6			
	·32	·0682	·0681
1·8			
	·60	·0798	·0796
1·5			
	·64	·0912	·0907
1·3			
		·1014	·1008

The third case investigated is that shown diagramatically in Fig. 2. ϕ' is a small positive angle and ϕ is nearly equal to π. In this case practically the whole of

Fig. 2.



the field is divided equally between the regions of shadow and reflexion (numbered I and III in the figures) and only a comparatively small portion (numbered II in the figure) is that occupied by the region of transmission. Both of the dividing boundaries fall in the region of the field under observation, and so far as this part of the field is concerned, the approximate theory of diffraction gives the same result as that found from the complete analytical solution satisfying the boundary condition $s=0$. The theoretical form of the illumination curve of a typical case of this kind is shown in Plate I Fig. 3 (a), and a photograph of the diffraction fringes is reproduced in Plate II Fig. 4 (a). Table IV shows the calculated position of the minima of illumination and the experimental data for comparison. The agreement is satisfactory.

TABLE IV.

$\lambda = 4410 \times 10^{-8}$ cm, $\phi' = 19' \, 40{\cdot}6''$,
$r = 3$ cm.

Calculated distances of the minima from the edge in cm.	Observed distances of the minima from the edge in cm.
−·0020	−·0020
·0051	·0051
·0103	·0104
·0149	·0152
·0193	·0194
·0232	·0235
·0269	·0273

§ 4. *Summary and Conclusion.*

The results arrived at from this investigation may be summarised as follows :—

(1) When plane waves of light are diffracted by the edge of a very obliquely held screen, the fringe system observed *at and near the surface of the screen on either side* shows features which require for their explanation, the complete analytical investigation of diffraction given by Sommerfeld. On one side of the screen, we have

the region of shadow, and adjoining at diffraction fringes, the maxima and minima of illumination of which show contrasts more marked than those in the diffraction fringes of the Fresnel type, their positions, however, being the same. This has been verified by photometric observation. On the other side of the screen, the fringes due to the interference of the direct and reflected wave-trains are observed, and these are modified by diffraction in a manner which can be fully explained only in terms of the complete analytical solution.

(2) The solution obtained by Sommerfeld with the boundary condition $s=0$ at the surface of the mirror, agrees with the results observed at oblique incidences, in the part of the field under discussion, irrespective of the plane of polarisation of the incident light.

The investigation described in this paper was carried out in the Palit Laboratory of Physics.

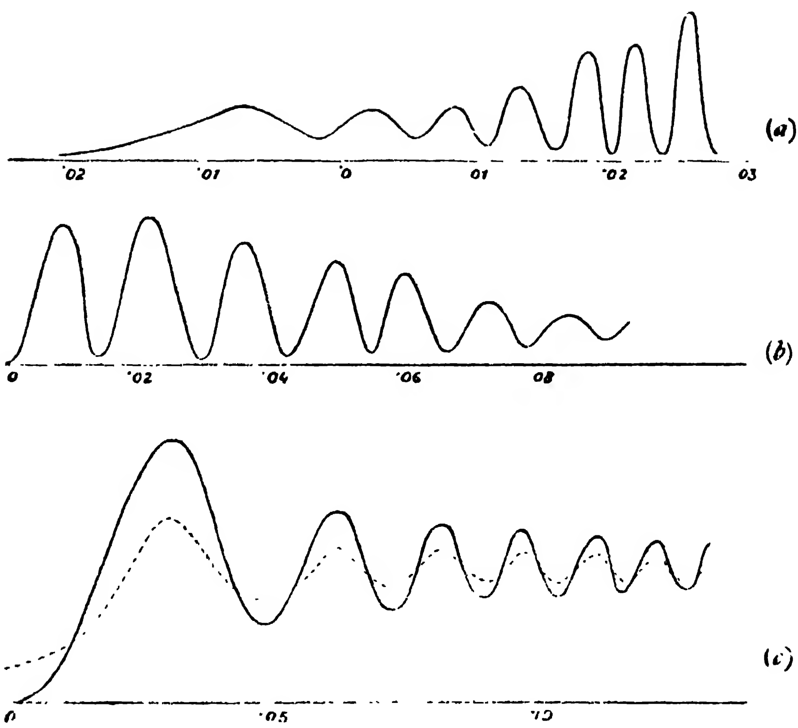


FIG. 3.

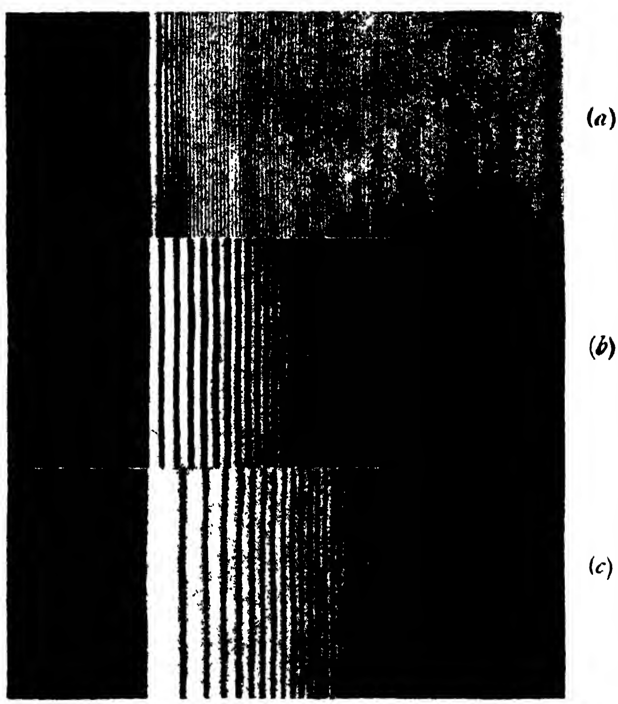


FIG. 4.

Illustrating oblique diffraction by a
Semi-infinite screen.

Chemical Section.

President of the Section:—Dr. P. C. Ray, C.I.E., Ph.D., D.Sc., *Sir Taraknath Palit Professor of Chemistry in the Calcutta University.*

The PRESIDENT delivered the following address:—

Gentlemen, I am going to give you a short account of the Chemical Work done in Bengal. Last year has been altogether an eventful one. It may be a little more than a year. Three Doctorates have been conferred on our students Dr. Rasiklal Datta is the first Doctor of Science in the Calcutta University in Chemistry. It is no breach of confidence and I am divulging no official secret when I say that in presence of our worthy Registrar (Dr. Brühl)—I am afraid that is adding to the enormity of the crime (laughter)—one of the Referees to whom Dr. Datta's paper was submitted said that his work marked a record in Chemical researches in India. But I am placing myself under the purview of the Official Secrets Act. Gentlemen, those who know Dr. Datta need not be told of the intrinsic value of his work. He has contributed some two dozen valuable papers and perhaps more. Then the Degree of Ph.D. has been conferred on Professor Panchanan Neogi. Again, the Degree of D.Sc. of the London University has been conferred on Mr. Nilratan Dhar, and Dr. Brühl had an opportunity of knowing him. Mr. Hartog, the academic Registrar of the London University, who as you know is present in Calcutta in connection with the University Commission, assured me the other day

that his Uuniversity has granted Dr. Dhar a research allowance. He has also obtained an additional recognition from the Royal Society in the shape of a research grant and his work must be regarded as very important. The work he has finished has been published in the journal of the Chemical Society. It covers some 50 or 60 pages. It is in continuation of the work he had taken in hand at the Presidency College. The work was begun in the atmosphere of Bengal (Cheers) and we can congratulate ourselves on his success. We shall no doubt have more Doctors at no distant time in the subject in which Dr. Ganesh Prasad has been training students ably but silently—namely, applied Mathematics. Some students are also engaged in good work outside Calcutta. At Dacca my namesake, though in a qualified form, has been steadily and devotedly working He drudges even in the climate of Bengal 12 hours a day and is keeping good health too! Two of his papers have appeared in the Chemical Society's Journal. We expect good results from the labours of Mr. Prafulla Chandra Ghosh. Then an apt pupil of ours Dr. Biman Behary De, is carrying on an important work on coumarin condensation. His forthcoming paper is also of a very high and interesting order. Then Dr. P. C. Mitter, also partially my namsake, our old pupil and a Ph.D. of Berlin, is not allowing the grass to grow under his feet. An important paper of his entitled, "Some Derivatives of Hydrazo and Azophthalides" worked out in collaboration with Mr. Jnanendranath Sen, Sir Rash Behary Ghosh Research scholar, will shortly appear in the Chemical Society's Journal.

One of the most remarkable papers is that of Mr. Jnan Chandra Ghose. It will soon appear in the London Chemical Society's Journal. He is following it up with another paper. I may be allowed to say that it is a contribution which marks a new era in the subject, namely, The Abnormality of Strong Electrolytes. It is a remarkable paper. This is the subject in which Van't Hoff, Arrhenius, Ostwald and many mighty workers have racked their brain. But it was left to Mr. Ghose to work out the Law which gives full explanation of the Phenomenon. His first paper covers about 9 pages but it has been followed by another of 18 pages and a third communication has also been made. These papers will throw a flood of light on one of the most interesting subjects in the domain of Physical Chemistry. To Dr. Nilratan Dhar also belongs the credit of being the pioneer in the field of Physical Chemistry in our land and of pointing out to our young enthusiastic friends the way to this fruitful line of research. Mr. Jnanendranath Mukerjee has published suggestive papers on Colloid Chemistry. Mr. Manik Lal Dey will just read a paper with experiments on a new phototropic salt. Its potentialities in the field of photography are obvious. These young scientists—the future hopes of our land—have kept up the fire and we expect many interesting contributions from them. I am not going to tire your patience by going into details of their merit. It is not my custom to take notice of any paper unless it has been accepted for publication in the leading Journals of Europe and America. We cannot afford to pass judgment on the work done by our own students

unless it has received the stamp of the learned societies abroad. At this important stage of scientific researches in our country it is proposed to start a journal in connection with scientific researches carried on at the Uuniversity College of Science.

Gentlemen, on the need of cultivating the Chemical Science . it is not necessary to say much. Every day we read news of chemical inventions. Even this morning we read in the newspapers that one of the biggest Chemical Works in Germany which used to supply nitrates and explosives, etc., was destroyed by fire. In modern warfare and in antiseptic surgery and the medicine—in destructive as well as in healing arts--Chemistry plays a prominent part and we cannot do better than take up the study of it. I had a talk with the manager of the Bengal Chemical and Pharmaceutical Works about an hour ago. He said that scarcely a day passed when he did not receive urgent telephonic communication from the munition department enquiring whether the firm could turn out this thing or that. I may tell you in passing that my Firm in its humble way is now turning out about two tons of magnesium sulphate a day and straining its capacity to its utmost to respond to the large orders from the Medical Stores, as also telegraphic orders for potash salts. It is a mistake to suppose that we can advance our industries unless we can make progress in Chemistry. It took a long time for Germany to realise this. They thought that all that they had to do was to begin applied Chemistry at once. But they soon discovered that they must continue the pursuit of Chemistry as an absolutely

theoretical science based upon a high standard before they could make any progress in industry When that position was secured the industrial progress became phenomenal. It is absurd to say that we can make progress in industrial Chemistry without at the same time making progress in theoretical Chemistry.

Gentlemen, I have omitted another name,—Dr. Sudhamoy Ghose is doing very good work for Sir Leonard Rogers. He is investigating into the constituents of Chaulmugra oil. His work is highly important from the point of view of treatment of tropical diseases. Chemistry, as you know, grew up as the handmaid of medicine. But we have now freed ourselves from the trammels of the physicians. At the early stages Chemistry was indissolubly associated with the department of medicine.

Now, gentlemen, I beg to renew my appeal on behalf of the Science Association. Mr Jagadindranath Lahiri has given a good account of his work as a research scholar of the Association. I hope some munificent donors will come forward and open their purse string to enable the society to keep him longer and also to found more scholarships. Funds are also necessary to enlarge the Laboratory. The Chemical Department of the Association is miserably fitted up. That is because there is no fund available. The spirit of the late Dr. Mahendra Lal Sircar is hovering over the building and I hope in the name of his sacred memory some munificent donors will come forward and help this Institute (Cheer).

Iodination by means of Nitrogen Iodide or by means of Iodine solution in the Presence of Ammonia.

By Dr. Rasik Lal Datta, D.Sc.,

and

Jagadindra Nath Lahiri, M.Sc.,

Research Scholar of the Association.

The systematic iodination by means of nitrogen iodide, or by means of a potassium iodide solution of iodine in conjunction with liquor ammonia has been tried in many cases by Datta and Prosad[1] with good results. In fact, they have shown that nitrogen iodide may be employed as a good iodinating agent. They have also shown that this method may be applied on a large scale since ammonia and iodine may be recovered. The following more cases have been studied to give a clear insight into the subject: 3-nitro-o-cresol has been found to yield 5-iodo-3-nitro-o-cresol and an ammonium salt. Anisole $C_6H_5.OCH_3$ gives a quantitative yield of polymer of o-iodo-anisole. 1 : 2 : 4-xylenol has been found to yield iodo-xylenol which could not be recrystallised from glacial acetic acid. Orcinol gives a quantitative yield of tri-iodo-orcinol. Fluoresein yields tetra-iodo-fluorescein. The following substances are charred with the formation of an iodo-derivative :—(a) Guacol, (b) Carvacrol, (c) Aniline, (d) m-toluidine. The special feature of the reagent is that in all cases quantitative yield of the product is obtained.

1 J Amer. Chem. Soc., 39, 441, (1917).

Iodination of 3-nitro-o-cresol.

3-NITRO-o-CRESOL. PREPARATION OF 5-IODO-3-NITRO-o-CRESOL AND ITS AMMONIUM SALT. 3-Nitro-o-cresol was prepared by passing nitrous gases through a solution of it in chloroform according to the method of Datta and Varma.

3-Nitro-o-cresol has not previously been iodinated. On iodination with iodine in presence of ammonia it yields the ammonium salt of 3-nitro-5-iodo-o-cresol, which yields the pure iodo-compound after recrystallisation from glacial acetic acid. 3-nitro-o-cresol is first dissolved in an excess of strong ammonia with warming on the water-bath. The solution acquires orange-red colour due to the formation of ammonium salt of 3-nitro-o-cresol. To this warmed orange-red solution, iodine in potassium iodide solution is added little by little with vigorous shaking, all the while the solution being kept on the water-bath. A precipitate begins to be thrown down at once, and the operation is stopped when no more iodine is taken up. The flask is heated and afterwards allowed to cool when needle-shaped orange-red crystals are obtained. These are filtered and washed with a very small quantity of water. These crystals are found to be soluble in water and give no melting point. Analysis indicates that it is the ammonium salt of monoiodo-3-nitro-o-cresol.

0.0648 gave 5.5 c.c N_2 at 32° C. and 760 mm.; N = 9.29.

Calc. for $C_6H_2I\ (CH_3)\ (NO_2)\ (ONH_4)$: N = 9.46.

A part of the substance was recrystallised from glacial acetic acid. Yellow needle-shaped crystals

were obtained melting at 84-85°, whose composition corresponds to mono-iodo-compound as indicated by the estimation of iodine.

$$0.0840 \text{ gave } 0.0705 \text{ AgI} ; \text{ I} = 45.32.$$
$$\text{Calc. for } C_6H_2I\ (CH_3)\ (NO_2)\ (OH) ; \text{ I} = 45.52.$$

Since positions 1, 2 and 3 are already occupied, the substance is 5-iodo-3-nitro-o-cresol. This is also confirmed by the fact that 3-nitro-o-cresol on bromination yields 5-bromo-3-nitro-o-cresol (m.p. 88°).

Hence 3-nitro-o-cresol on iodination yields 5-iodo-3-nitro-o-cresol.

Anisole, $C_6H_5.OCH_3$.

PREPARATION OF POLYMER OF o-IODO-ANISOLE :

The iodo-derivative is prepared in the following manner :—

Anisole is slightly soluble in liquor ammonia. A few drops of anisole is heated on the water-bath with an excess of ammonia. The solution is coloured green due to the solution of some of the anisole in ammonia. To this solution, containing some portion of undissolved anisole, iodine in potassium iodide solution is added drop by drop and at the same time the solution is heated on the water-bath with constant shaking. After adding an excess of iodine in potassium iodide solution and heating on the water bath pale reddish precipitate is formed. The solution with the precipitate is heated gently on the water-bath to ensure the complete decomposition of nitrogen iodide which may have been formed by the interaction of an excess of

iodine with ammonia. The precipitate is filtered off and washed with water and afterwards dried on a porous plate. It is recrystallised several times from glacial acetic acid. Its m.p. in each case is found to be 156-157°. Hence it is a pure substance.

0.0648 gave 0.0623 AgI ; I = 52.02.

Calc. for $C_6H_4I.OCH_3$; I = 54.27.

This new substance is a mono-iodo-derivative of anisole. According to the law of substitution iodine atom will enter into ortho-and the para positions simultaneously. But since the substance is a pure one and gives the same melting point after recrystallisation for several times from glacial acetic acid, the iodine atom will have entered either the ortho or the para position to the $\cdot OCH_3$ group. But from the result of the replacement of iodine atom by nitro group it has been found that the iodine atom has entered the position 2 corresponding to $.OCH_3$ group 1. Hence the compound in question is o-iodo-anisole.

In a paper on iodine derivatives of anisole (Migration of an iodine atom) by Frederick Reverdin[1], it was found that o-iodo-anisole is an oil having b.p. 239-240° by 730 mm. and that this o-iodo-anisole yields on nitration 2, 4-iodo-nitro-anisole m.p. 95-96°. But our substance was found to have a m.p. of 156-157° after several times recrystallisation from glacial acetic acid and it was found to be a mono-iodo-anisole. Hence the substance is a polymer of o-iodo-anisole since on nitration it yields 2, 5-dinitro-anisole.

1. Ber., 1896, 29, 997-1005;

Iodination of 1 : 2 : 4-Xylenol.

XYLENOL-(CH_3 : CH_3 : OH = 1 : 2 : 4).

PREPARATION OF IODO-XYLENOL.

This substance had not been previously iodinated. Xylenol is dissolved in a very large excess of ammonia. The solution is then heated on the water-bath and to it iodine solution is added which is taken up and at the same time a dirty white precipitate begins to be deposited. The addition of iodine is continued with warming until no more of it is taken up. At the end, a green ppt. is left behind, which is not soluble in ordinary solvent namely glacial acetic acid, alcohol etc. Glacial acetic acid seems to decompose the iodinated product with liberation of iodine; but it cannot be recrystalised from the acid. The resulting green product is soluble in acetone but cannot be recrystallised from it. It extracts an oily product which after a day becomes semi-solid. The product from glacial acetic has a deep brown colour without any m.p. and without any crystalline shape.

The green iodinated product is found to decompose with charring at about 115°-120°. It appears that the substance is a polymeric product and hence cannot be recrystallised from any solvent.

$$\text{ORCINOL.}\quad C_6H_3\begin{cases} .CH_3 & (1) \\ .CH & (3) \\ .OH & (5) \end{cases}$$

FORMATION OF TRI-IODO-ORCINOL.

It was first prepared by Stenhouse[1] by the action of iodine chloride on orcinol.

Orcinol is dissolved in liquor ammonia and the

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1. A., 134, 312.

solution thus obtained is heated on the water-bath until effervescence due to the escape of ammonia takes place. A clear red solution is obtained. To this hot solution, iodine dissolved in KI solution is added drop by drop with constant shaking. Immediately a heavy deep reddish brown precipitate is formed. Iodine solution is added until no more is taken up by the solution. The resulting precipitate is filtered and found to be soluble in carbon disulphide. It cannot be recrystallised and has got no m.p. It is found on analysis to be tri-iodo-orcinol.

FLUORESCEIN. PREPARATION OF TETRA-IODO-FLUORESCEIN OR ERYTHROSIN. Fluorescein has been previously iodinated by the action of iodine to an alkaline solution of fluorescein with the formation of tetra-iodo-fluorescein. This is prepared more readily and in better yield by the action of iodine on an ammoniacal solution of fluorescein. Some fluorescein is taken in a flask and liquor ammonia is added, when most of it dissolves on shaking. The last traces are dissolved by heating on the water-bath. To the green fluorescent solution a solution of iodine in potassium iodide is gradually added while the solution is still warm. The iodine seems to be taken up at first but when the solution is somewhat cooled, nitrogen iodide is precipitated. This is taken up by shaking and heating on the water-bath at the same time. Some more iodine solution is added. It is shaked and warmed. After continued warming on the water-bath, and with subsequent addition of iodine solution the green fluorescence gradually disappears with the formation of a pink solution and

immediately magenta-like crystals are precipitated. Iodine solution is added until no more is taken up by the solution. When the green fluorescence has completely disappeared the precipitate is filtered off and dried. The crystals are found to be glistening magenta-like and slightly soluble in water. It is found on analysis to be tetra-iodo-fluorescein or erythrosin.

PHENETOLE, $C_6H_5.OC_2H_5$ Iodine in presence of ammonia has no action on phenetole.

2,4-DINITROPHENOL. Iodine in presence of ammonia has no action on 2, 4-dinitrophenol.

o-NITROANILINE. Iodine in presence of ammonia has no action on o-nitroaniline.

GUIACOL. This substance is not completely soluble in liquor ammonia. But when iodine solution in potassium iodine is added to an ammoniacal solution of guiacol, the substance is charred with the formation of iodo-guiacol.

ANILINE, $C_6H_5.NH_2$. Aniline is not completely soluble in liquor ammonia. A small amount of aniline is taken into a flask and heated on the water-bath with liquor ammonia. Iodine in potassium iodide solution is added drop by drop. A red precipitate begins to form. On further addition of iodine solution, the red precipitate is found to be charred. Hence, iodine in presence of ammonia chars aniline with the formation of iodo-aniline.

m-TOLUIDINE. m-toluidine is not completely soluble in liquor ammonia. When iodine solution is added to m-toluidine in liquor ammonia the latter is immediately charred with the formation of an iodo-derivative.

CARVACROL, $C_6H_3 \cdot \begin{cases} CH(CH_3)_2 & (1) \\ OH & (3) \\ CH_3 & (4) \end{cases}$. Carvacrol is not completely soluble in liquor ammonia. A portion of it is dissolved when heated on the water-bath with liquor ammonia. The solution assumes a green colour. To the solution containing dissolved and undissolved carvacrol, iodine in potassium iodine solution is added drop by drop with constant shaking and at the same time the solution is heated on the water-bath. Immediately undissolved carvacrol is charred with the formation of an iodo-derivative. On further addition of iodine solution, the whole of the carvacrol is charred with the formation of an iodo-compound.

6-NITRO-m-CRESOL. This substance was prepared by passing nitrous gases through a chloroform solution of the substance.

Iodine in ammoniacal solution of the substanee has no action.

Replacement of Iodine Atoms by Nitro Groups in Phenolic Bodies.

By

Dr. Rasik Lal Datta, D.Sc.

and

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It has frequently been observed, even under the mildest conditions of nitrations, that the nitro-group is capable of displacing a bromine atom in phenol; thus Robertson[1] showed that nitric acid converts 2 : 6-dibromo-4-acetyl-aminophenol in dilute nitric acid solution into the o-nitroderivative with liberation of bromine. Robertson and Briscoe[2] had shown that in some cases migration of halogen atom takes place by the action of acid. Thus 6-chloro-thymol was converted by means of nitric acid into 2-chloro-6-nitrothymol and 6-bromothymol by the same treatment into 2-bromo-6-nitrothymol. Dahmer[3] had also shown that many bromo-compounds give up bromine atom with the formation of a nitro-derivative even with the action of nitrous acid. Thus he had shown that 6-bromothymol and 2, 6-dibromothymol is converted into 2-nitro-6-bromothymol, 2 · 4-dibromo-α-naphthol into 2-nitro-4-bromo-α-naphthol and 1 : 6-dibromo-β-naphthol into 1-nitro-6-bromo-β-naphthol Similarly, T. Zincke[4] had shown that 3, 5-dibrom-o-cresol was converted into 3-nitro-5-bromo-o-cresol by

1. Trans., 1902, 81, 1417.
2. J. Chem. Soc., 1912, 101, 1962.
3. Ann., 1904, 333, 346.
4. J. Pr. Chem. 1900 (2) 61, (5) 61-67.

the action of nitrous acid. Other cases were studied by T. Zincke and he had observed that nitrous acid is capable of displacing bromine atom in bromo-compounds with the formation of a nitro-derivative. Faust[1] had shown that 2 : 4 : 6-trichlorophenol was converted into dichloroquinone by the action of nitric acid. The replacement of iodine by nitro-group has not been practically studied with the exception of one or two isolated cases. Robertson and Briscoe[2] have shown that 6-iodo-thymol liberates Iodine by the action of strong HNO_3 in glacial acetic acid solution. The object of the present investigation is to systematise the reaction and find out the conditions under which the replacement takes place and also to prepare mixed nitro-haloid derivatives of phenols which otherwise could only be obtained indirectly and passing through many steps. This reaction has also been used with advantage to elucidate the constitution of many iodophenols of unknown constitution since it has been found that the nitro-group takes the place previously occupied by the iodine atom.

The results that have been obtained are interesting : Tri-iodophenol gives a quantitative yield of 2, 6 diiod-4-nitrophenol. 2, 6-diiod-4-nitrophenol gives on further action quantitative yield of 2, 4, 6-trinitrophenol. Triiodo-m-cresol gives a quantitative yield of 2, 4, 6-trinitro-m-cresol. 5-iodo-3-nitro-p-cresol gives a quantitative yield of 3, 5-dinitro-p-cresol. 2 iodo-3-nitrophenol also gives a quantitative yield of

1. Ann., 1869, 149, 153.
2. J. Chem. Soc., 1912, 101, 1964.

2, 3-dinitrophenol. 5-iodo-3-nitro-o-cresol, forms a decomposition product. Iododerivatives of 1 : 4 5-xylenol and 1 : 2 · 4-xylenol are decomposed with liberation of iodine by the action of nitric acid. Mono-iodo-anisole gives 2, 5-dinitro-anisole. Nitric acid, either strong or dilute, has no action on 5-iodo-salicylic acid and Tetraiodophenol-phthalein.

Experimental

TRIIODOPHENOL PREPARATION OF 2, 6-DIIOD-4 NITROPHENOL.

2, 6-diiod-4-nitrophenol was first prepared from 4-nitro-phenol by the action of iodine and iodic acid in an alcoholic solution of the former[1] It was also prepared by Post and Brackebusch[2] by the action of iodine and mercury oxide on an alcoholic solution of o-sulphonic acid of 4-nitrophenol Weselsky[3] also prepared it from 5-nitrosalicylic acid by the action of iodine and mercury oxide.

Triiodophenol, when heated on the water-bath with a 50% nitric acid solution in a test tube for a few minutes, evolves iodine, the evolution being rapid at first. The resulting product is further heated on the water-bath with constant stirring by means of a glass rod to drive the whole of the liberated iodine. When neither the violet colour nor the smell of the iodine is noticeable, the resulting nitro-compound is filtered off, washed with water to eliminate the nitric acid and dried on a porous plate. It is recrystallised from ether and is found on analysis, to be 2, 6-diiodo-

1. Korner, Z, 1868, 324
2 A., 205, 91.
3. A, 174, 107.

4-nitrophenol. It melts at 155°-156°. The yield is almost quantitative.

When large amount of triiodophenol is taken at a time and subjected to the above process there is a great chance of the substance to be charred owing to the liberation of the whole of the iodine at once but which can however be prevented by the gradual addition of nitric acid.

TRIIODOPHENOL. FORMATION OF 2, 4, 6-TRINITROPHENOL.

The 2, 6-diiodo-4-nitrophenol obtained from triiodphenol is again heated on the water-bath in a test-tube with 50% nitric acid with constant shaking. Violet vapour of iodine is evolved within a short time. The substance with the acid is heated further on the water-bath with repeated shaking to expel the whole of the liberated iodine. When no more iodine is seen to evolve the resulting nitro-compound is filtered off, washed with water and a small portion dried and tested for iodine. No trace of iodine in the substance could be found. The resulting substanee is recrystallised from alcohol and is identified to be 2, 4, 6-trinitrophenol melting at 122°-123°. The yield is very small. The action of strong nitric acid in case of triiodophenol is very rapid. Copious evolution of iodine takes place and at the same time the substance is charred.

This 2, 6-diiodo-4-nitrophenol was also prepared from p-nitrophenol according to Datta and Prosad[1] by the action of iodine solution on ammoniacal solution

1. J. Amer. Chem. Soc., 39, 441 (1917).

of the substance. This is also similarly treated with nitric acid with the formation of 2, 4, 6-trinitrophenol.

2, 4-DIIODO-6-NITROPHENOL. FORMATION OF 2, 4, 6-TRINITROPHENOL.

2, 4-diiodo-6-nitrophenol is prepared from o-nitrophenol by the action of iodine upon the solution of the former in liquor ammonia[1]. A small amount of this is heated on the water-bath with 50% nitric acid. The temperature of the bath is kept at 80°-85°. After a few minutes violet vapour of iodine is seen to evolve. The substance with the nitric acid is heated carefully to drive off the liberated iodine. After heating for a long time it is found that the substance is dissolved leaving behind a very few small crystals of iodine. These iodine crystals are dissolved out by the nitric acid solution with further heating.

Several operations like above are repeated and the nitric acid solution of the resulting substance in each case is mixed together and carefully evaporated on a water-bath. When all the iodine and nitric acid is driven out, small yellow crystals are seen to form and these are again dissolved in hot distilled water and evaporated so as to get pure crystals, the evaporation being carried out carefully so as not to decompose the crystals which are formed. These crystals are filtered off, recrystallised from hot alcohol. It is found to melt at 121°-122°. It is identified to be 2, 4, 6-trinitrophenol. The yield is almost quantitative.

When large amount of di-iodo-nitrophenol is taken and treated in the above way, a part of the resulting

1. Datta & Prosad, J. Amer. Chem. Soc., 39, 441 (1917).

nitro-compound is dissolved while the portion left behind remains in a liquid state with iodine at the temperature of boiling water. In this case, it is very difficult to drive the liberated iodine completely.

TRIIOD-m-CRESOL. FORMATION OF 2, 4, 6-TRINITRO-m-CRESOL.

Triiod-m-cresol is prepared by the method of Datta and Prosad[1] from m-cresol. A small amount of triiod-m-cresol is treated with 50% nitric acid at the ordinary temperature. Some action takes place and iodine is set free. To promote the action and at the same time to drive off the liberated iodine the mixture of the substance and the acid is heated on the water-bath for some time with constant stirring. Copious evolution of iodine takes place which is carefully expelled on heating on the water-bath. The resulting nitro-compound is filtered off, washed with water and dried. A small amount of the substance is tested for iodine and it was found to be all expelled. The substance is recrystallised and is identified to be 2, 4, 6-trinitro-m-cresol melting at 105°-106°. The yield is quantitative.

5-IODO-3-NITRO-p-CRESOL. FORMATION 3, 5-DINITRO-p-CRESOL.

5-iodo-3-nitro-p-cresol is prepared by dissolving 3-nitro-p-cresol in ammonia and adding solution of iodine in potassium iodide solution while heating on the water-bath[1]. A small amount of this iodo-nitro-p cresol is heated with 50 % nitric acid solution on the

1. J. Amer. Chem. Soc., 39, 441 (1917).

water-bath in a test-tube with constant shaking, the temperature of the bath being kept at 70°. After a few minutes copious evolution of iodine is seen to take place. The substance is further heated so as to ensure the complete elimination of liberated iodine. When no more iodine is seen to evolve it is filtered and washed with water to free the resulting nitro compound from nitric acid. The substance on drying melts at 84° and is identified to be 3, 5-dinitro-p-cresol. The yield is almost quantiative.

MONO-IODO-ANISOLE. PREPARATION OF 2, 5-DINITRO-ANISOLE= $CH_3O.C_6H_3(NO_2)_2$.

Mono-iodo-anisole is heated on the water-bath with 50 % nitric acid solution in a test tube with constant shaking. After a few minutes, liberation of iodine takes place and consequently nitric acid solution deepens in colour due to the solution of some of the iodine in it. The substance with the acid solution is heated on the water-bath for 5 to 6 hours to drive off the liberated iodine. When it is seen that no more iodine is evolved with the application of heat the resulting nitro-compound is filtered off, washed with water to free it from nitric acid and dried on porous plate. It melts at 94°-96°. Small quantities of iodo-anisole should be taken at a time otherwise the mixture chars with considerable liberation of iodine The resulting nitro compound is identified to be 2, 5-dinitroanisole $CH_3O.C_6H_3(NO_2)_2$.

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1. Datta and Prosad, J. Amer. Chem. Soc., 39, 441 (1917).

Determination of position of iodine atom in mono-iodoanisole :—

When anisole is iodinated by means of the nitrogen iodide method of Datta and Prosad, it is found on analysis to yield a mono-iodo-derivative. Now according to the law of substitution iodine atom will enter into the ortho and para positions to the methoxyl group simultaneously. But since the mono-iodo-derivative gives the same m.p. after recrystallisation for several times from glacial acetic acid the substance, which we are dealing with, is a pure one and consequently iodine atom will have entered either ortho or para position to the methoxyl group. Hence from the result of the replacement of iodine by nitro-group it is clearly evident that iodine atom has entered the position 2 corresponding to $\cdot OCH_3$ group I and the iodoanisol obtained by iodination is o-iodanisol.

In a paper by Frederick Reverdin[1] on iodine derivative of Anisol (Migration of an iodine atom) it is found that o-iodo-anisole is an oil having b.p. 239°-240° by 730 mm. This o-iodo-anisole on nitration yields 2, 4-iodnitroanisol ($\cdot OCH_3 : I : NO_2 = 1 : 2 : 4$) m.p. 95°-96°. Hence from above, it is clear that iodoanisole which is obtained after iodination of anisole is a polymer of o-iodanisole.

2-IODO-3-NITROPHENOL. FORMATION OF 2, 3-DINITROPHENOL.

Bantlin[2] prepared it from 2, 5-dinitrophenol. Wender[3] prepared it from methylather of dinitrophenol.

1. Ber., 1896, 29, 997-1005.
2. B., 11, 2104.
3. G., 19, 222.

m-Nitrophenol is iodinated with the formation of 2-iodo-3-nitrophenol by means of nitrogen iodide method of iodination of Datta and Prosad.[1] A small amount of this iodo-nitrophenol is treated with 50 % nitric acid solution in a test tube and heated on the water-bath. After prolonged heating for hours iodine is liberated. The action is very slow; even hours are required to displace the whole of the iodine Consequently strong nitric acid is tried. A small quantity of 2-iodo-3-nitrophenol is treated in the usual way with strong nitric acid. The nitric acid is coloured reddish violet due to the liberation of iodine. To promote the action and at the same time to eliminate the liberated iodine, the original substance with strong nitric acid is heated in a big test tube on the water-bath with constant shaking. With slight heating copious evolution of iodine takes place as recognised by its smell and violet colour. After a few minutes' heating on the water-bath it is found that whole of the iodine has been liberated, tiny little crystals of which are noticeable in the test tube while the resulting nitro-compound remains in solution. This nitric acid solution of the substance with little crystals of iodine is poured in an evaporating basin and evaporated on the water-bath. Liberated iodine is completely expelled. Further concentration on the water-bath results with the formation of yellow crystals. These crystals are again redissolved in very dilute nitric acid and evaporated on the water-bath so as to get pure crystals. After several times recrystallisation from dilute nitric acid, the substance

1. J Amer. Chem. Soc., 39, 441 (1917).

is dried on porous plate. It is identified to be 2,3-dinitrophenol. It melts at 145°-146.° The yield is almost quantitative.

5-IODO-3-NITRO-o-CRESOL. FORMATION OF A DECOMPOSITION PRODUCT.

This substance is prepared by the iodination of 3-nitro-o-cresol by the nitrogen iodide method. A small amount of this iodo-nitro-cresol is treated in a test tube with concentrated nitric acid. All the while the test tube with the substance is kept in a water-bath, the temperature of which is maintained at 70°. After heating for a few seconds copious evolution of iodine takes place. The substance is stirred all the while with a glass rod. Within a few minutes tiny little crystals of iodine are found in the test tube while the resulting nitro-compound is dissolved by the nitric acid. The nitric acid solution of the resulting substance together with liberated iodine is heated on the water-bath in order to ensure the complete elimination of liberated iodine. After a time, all the iodine is expelled and the solution is evaporated so as to get crystals. On complete evaporation, a very small amount of pasty substance is found. It is hygroscopic and its m.p. cannot be determined. Hence, it is a decomposition product.

DI-IODO-o-CHESOL.

50% nitric acid solution acts vigorously upon di-iodo-o-cresol. Rapid evolution of iodine takes place and the substance is immediately charred. Consequently very dilute nitric acid is employed. Some of the original substance is heated with very dilute nitric acid solution on the water-bath (in a test-tube) the

temperature of which is very carefully regulated. It is kept between 50°-55.° After a few minutes, evolution of iodine takes place with the formation of a nitro-compound. The resulting product is carefully heated in presence of the acid solution until all the liberated iodine is driven out and at the same time taking necessary care for the regulation of the temperature.

It has been found that the dilute nitric acid solution replaces the iodine of the original substance very slowly without the application of any external heat. Hence, to promote the action it is heated on the water-bath the temperature of which is not allowed to raise above 55.° The resulting compound is filtered and recrystallised from ether. Its m.p. is carefully determined which is found to be 61°-62. Repeated crystallisation resulted in the formation of a pure substance, the m.p. in each case remaining constant viz., 61°-62.° The resulting substance is a new one and is under analysis.

In this case, it is very difficult to drive out the liberated iodine completely. The temperature cannot be raised over 62°; otherwise the substance will be charred immediately.

3, 5-DI-IODO-p-CRESOL.

This substance is immediately charred when treated with 50% nitric acid solution. The original substance is treated with dilute nitric and heated on the water-bath taking care not to raise the temperature of the bath above 50°. Evolution of the iodine takes place. The resulting substance is heated with the acid until all the liberated iodine is driven off. The final product is recrystallised from ether and m.p. determined. It

is found to be 54.° In this case it is found that the substance remains in a semi-liquid state with the liberated iodine and consequently it is found very difficult to drive off the liberated iodine. Notwithstanding this, it is very difficult to prepare it in a pure state. One more difficulty that is encountered with is that the substance with the liberated iodine cannot be heated over 54° for fear of charring. However, the substance is recrystallised from ether and is under analysis.

MONOIODO-1 : 4 : 5-XYLENOL. FORMATION OF A CHARRED PRODUCT.

50% nitric acid solution has been found to liberate iodine slowly in the cold but strongly on heating. After heating for a while with care the substance is found to char with liberation of iodine. Dilute nitric acid has the same effect on the iodo-compound of 1 : 4 : 5-xylenol. Strong nitric acid chars it with liberation of iodine.

In the case of iodo-derivative of 1 : 2 : 4-xylenol, nitric acid has been found to have the same effect. It chars the substance with liberation of iodine.

5-IODO-SALICYLIC ACID. No action with strong HNO_3 acid. 5-iodo-salicylic acid is prepared by the nitrogen iodide method of iodination of Datta and Prosad.[1] The resulting iodo-compound has been treated with hot strong nitric acid. But no action is observed.

TETRAIODOPHENOLPHTHALEIN. No action with strong nitric acid. Tetraiodophenolphthalein was prepared by the action of solution of iodine

1. J. Amer. Chem. Soc., 33, 441 (1917).

in potassium iodide on a solution of the substance is liquor ammonia.[1] This resulting teraiodo-compound was found to have no action when heated with strong nitric acid.

Indian Association for the Cultivation of Science.

1. Datta & Prosad, J. Amer. Chem. Soc., 39, 441 (1917).

Mercuric Sulpho Iodide.
A case of Reversible Phototropy.

By

Manik Lal Dey, M.Sc.

A Preliminary Note.

When water, saturated with hydrogen sulphide, is gradually added to a boiling solution of mercuric iodide in aqueous potassium iodide or ammonium chloride, a yellow colloidal solution is formed from which an orange yellow precipitate is obtained on addition of hydrochloric acid. This precipitate is found on analysis to conform to the empirical formula $Hg_3S_2I_2$. It is insoluble in all the ordinary solvents; also carbon disulphide and potassium iodide solution do not extract anything from it.

When exposed to light the orange yellow colour is gradually turned grey and finally black. On keeping the black substance in the dark the change occurs in the reverse way and finally the original colour is regained. In direct sunlight the substance takes only half a minute to turn completely black. At elevated temperatures the reverse change takes place more rapidly. Thus at 85°C the black substance regains the original orange yellow colour in 10 seconds. The two varieties of the substance are of the same chemical composition, and probably here we have a case of isodynamic change related to colour which Markwald calls reversible phototropy.

The similarity of both physical and chemical properties of this compound with those of $(SHgI)_2$ obtained by Dr Rây (Trans Chem. Soc., 1917, Vol. III, p. 109) leads one to suppose that the probable constitution of this compound is

$$Hg \langle \begin{matrix} SHgI \\ SHgI \end{matrix}$$

Biological Section.

President of the Section—Dr. B. L. Chaudhuri,
D.Sc., F.L.S., F.R.S.E.

Presidential address :—

A
Short Summary of Darwinism as modified by Mendel's Law and the Theory of Mutation.

What Darwinism is and what it involves may be disputed, but on this point Poulton in his essays on Evolution considers the factors to be :—

(1) individual variation,

(2) the fact of heredity, *i.e.*, an inheritance of variation, and

(3) the sturggle for existence *i.e.*, an elimination of the individual possessing the less fit variations and a preservation of the fit ones by the struggle for existence—Natural Selection.

Recognisable differences in progeny, minute or marked, may be termed variations.

They were recognised by Darwin as falling into two distinct kinds :—

(1) fluctuating or continuous variations and

(2) discontinuous variations or sports (afterwards termed as mutations by de Vries).

Though Darwin recognised these two distinct classes of variations he believed that the discontinuous variations occurred rarely and would be liable to be

swamped by inter-crossing. Darwin, therefore, believed that the Evolution was due to the occurrences of the continuous variations and their inheritance.

On examination many of these continuous variations were found to be due to environment or artificially produced.

Professor August Weismann of Freiburg proved that the power of hereditable variation lay in the primitive germ-cells of the sexual glands, denied the transmission of acquired peculiarities and justified this denial conclusively as there is no accurate or approximately accurate fact in support of the theory of transmission to the offspring of a mutilation suffered by the parent.

Weismann, however, failed fully to explain how the individual varying characters comported themselves in transmission. And the Drawinians, who held that environment produced variations on the body of the individual, were still struggling to get the supposed somatic variation conveyed to the germ-cells and thus passed on to the progeny. The biologists came to be thus involved in the solution of the facts of heredity.

There are no scientific problems of greater human interest than those of Heredity—which may be defined as the genetic relation between successive generations.

The issues of the individual life are in great part determined by what the living creature is or has to start with.

Life nevertheless implies persistant action and reaction between organism and environment. Great importance undoubtedly attaches to environment in

the widest sense,—food, climate, housing, scenery &c., and also to function in the widest sense,—exercise, education, occupation, or the lack of these.

Thus (1) what the living creature is or has to start with in virtue of its hereditary relation (its genetic relation to its fore-fathers), (2) what it does in the course of its activity, and (3) what surrounding influences play upon it,—these are the three determining factors of life. Therefore heredity, function and environment are the three sides by the consideration of which a formed character can be scientifically analysed. But the potent influences of environment and function act upon an organism whose fundamental nature is already determined by its heredity, *i.e.* by its genetic relation to its fore-parents.

Naturally enough the reappearnce in the offspring of qualities which characterised its parents or its ancestors has been persistently likened to the inheritance of a legacy but this is to some extent a metaphorical expression, and not without its dangers. In regard to property there is a clear distinction between the heir and the estate which he inherits, but at the begining of an individual life we cannot biologically draw any such distinction. The organism and its inheritance are, *to begin with*, one and the same.

Every living creature arises from a parent or from parents more or less like itself; this reproductive or genetic relation has a visible material basis in the germinal matter (usually egg-cell and sperm-cell about which we will have to refer in detail presently) liberated from the parental body or bodies; by inheritance we mean all the qualities or characters

which have their initial seat, their physical basis, in the fertilised egg-cell; the expression of this inheritance in development results in the organism. Thus, heredity is no entity, no force, no principle, but a convinient term for *the genetic relation* between successive generations, and inheritance includes all that the organism is or has to start with in virtue of its hereditary relation.

In other departments of science also there has been a reduction in the number of supposed separate powers or entities. "Caloric" was one of the first to be eliminated, yielding to the modern interpretation of heat as "a mode of motion;" "Light" had to follow, when the undulatory or the electro-magnetic theory of its nature was accepted; a specific "Vital force" is disowned even by the Neo-vitalists; "Force" itself has become a mere measure of motion; and even "Matter" tends to be resolved into units of negative electricity, carrying with them a bound portion of the ether in which they are bathed; and so on. In view of this progress towards greater precision and simplification of phraseology, sooner we get rid of any such term as principle of heredity or force of heredity the better for clear thinking since heredity is certainly no power, or force, or principle, but a convenient term for the relation of organic or genetic continuity which binds generation to generation. Ancestors, grand- parents are real enough; children and children's children are also very real; heredity is a term for the relation of genetic continuity which binds them together. We have to study it as a relation of resemblances and

differences which can be measured or weighed, or in some way computed; we, therefore, have to speak of the science of heredity, the study of which is not only of practical importance to breeders and cultivators, to medical practitioners; to educationists, to social reformers, and to actual and prospective parents but also is of fundamental importance in the domain of pure science, in the biologist's attempt to interpret the process of evolution by which the complexities of our present-day fauna and flora have gradually arisen from simpler antecedents. For heredity is obviously one of the conditions of evolution, of its continuance as well as of progress.

No one has done more to further the scientific study of heredity than Weismann who has done for the study of heredity what Dalton with his atomic theory did for chemistry.

The modern science of heredity in fact has been established out of his profound study on its physical basis which he has termed germ-plasm and his theories of continuity of germ-plasm and germinal selection. The experimental researches of Mendel and his followers on breeding and hybridisation have built up the science and the Mutation Theory of de Vries founded on the discovery by him of the fact and instances of discontinuity in variation has removed all doubts and difficulties in proving the laws otherwise reached by Mendel and Weismann. We will now briefly attempt to touch on these interesting topics.

The living organism may be compard to an engine, *i.e.*, a material system adapted to transform matter and energy from one form to another; but it is a

self-repairing engine, and it is able to do what no engine can ever aspire to effect *i.e.* it is able to reproduce similar engines like itself.

Thus one of the most characteristic properties by which the living beings can be at once distinguished from the non-living things, is the tendency of a living being to undergo cyclical changes, *i.e.*, the power of reproducing new individuals perfectly similar to itself.

In the ordinary course of nature, all living matter proceeds from pre-existing living matters a portion of the latter being detached which acquires an independent existence. The new form takes on the character of that from which it arose and exhibits the same power propagating its own kind by means of similar off-shoot.

The production of offspring in ancient times used to be held to be similar to the production of a crop from seed. The seed came from the male-parent the female parent was said to provide the soil.

The physical basis of heredity could not and in fact did not become established until the recognition of mother as more than a passive agent.

That recognition was effected by the microscope which made the actual observation of the minute sexual cells possible.

By the end of the eighteenth century only, the scientific men came to the definite conclusion that each of the sexes makes a definite material contribution to the making of offspring.

Among the higher plants the female sexual cells are borne by the ovules and the male sexual cells in

the pollen grains. Among animals the female contributes the ovum, the female sexual cell and the male, the sperm cell or Spermatozoon.

The individual life of the great majority of plants and animals begins in the union of two minute elements—the sperm cell and the egg-cell.

These microscopic individualities unite to form a new individuality, a potential offsping which will gradually develop into a creature like its parents.

To the above statement a few exceptions must be made :—

(1) for bananas, which have no longer any seeds,

(2) for potatoes which are multified by cutting,

(3) for the drone-bees and summer green-flies who have mothers but no fathers ;

and (4) for simple unicellular organisms in which there is no sexual reproduction ;

but the exceptions are trivial compared with the vast majority of living creatures in regard to which it is certain that each life begins in a fertilised egg-cell.

As a general rule it may be stated that the reproductive cells produced by the female parent are relatively larger and without the power of independent movement. These cells are more or less heavily loaded with the yolk substance that is to provide for the nutrition of the developing embryo during the early stages of its existence.

The male sexual cells are always of microscopic size and are produced in the generative gland or testes in exceedingly large numbers. In addition to their minuter size they differ from the ova in their power of

active movement. The spermatozoon is endowed with some form of motile apparatus often a long flagellum or a whip-like process, by the lashing of which the little creature propels itself much as a tadpole with its tail.

In plants as in animals the female cells are larger than the male cells, though the disparity in size is not nearly so marked. Still they are always relatively minute. The ovules are found surrounded by maternal tissue in the ovary but through the stigma down the pistil a potential passage is left for the male cell. The majority of flowers are hermaphrodite, *i.e.*, the male and female elements occurring in the same flowers, and in many cases they are also self-fertilising. The anthers burst and the contained pollen grains are then shed upon the stigma. When this happens, the pollen cell slips through a little. hole in its coat and bores its way down the stigma to reach an ovule in the ovary. Complete fusion occurs, and the minute embryo of a new plant immediately results. But for some time it is incapable of leading a separate existence, and, like the embryo mammal, it lives as a parasite upon its parent. By parent it is provided with the seed-coat, and beneath this the little embryo swells until it severs its connection with the parent organism.

It is important to realise that the seed of a plant is not a sexual cell but a young individual which, except for the coat that it wears, belongs entirely to the next generation.

There is some parallelism between a seed of a plant with a pupa of a butterfly. During one summer

they are initiated by the union of two sexual cells and pass through certain stages of larval development —the butterfly as a caterpillar, the plant as a parasite upon its mother plant. As the summer draws to a close, each passes into a resting-stage against the cold weather—the embryo-butterfly as a pupa and the embryo-plant as a seed, with this difference, that while the caterpillar provides its own coat, that of the plant is provided by its mother With the advent of spring both butterfly and plant emerge, become mature, and themselves ripen germ-cells which give rise to another new generation.

Whatever be the details of development, one cardinal fact is clear. Except for the relatively rare instances of partheno-genesis, a new individual, whether plant or animal arises as the joint product of two sexual cells derived from individuals of different sexes. Such sexual cells, whether ovum cells or sperm cells, are known by the general term of *gametes* or marrying cells, and the individual formed by the fusion or yoking together of two gametes is spoken of as a *zygote*.

Since a zygote arises from the yoking together of two separate gametes, the individual so formed must be regarded throughout its life as a double structure in which the components brought in by each of the gametes remain intimately fused in a form of partnership. But when the zygote in its turn comes to form gametes the partnership is broken and the process is reversed. The component parts of the dual structure are resolved with the formation of a set of single structures, the gametes.

Thus among the higher plants and animals the life cycle falls into three stages.

(1) Isolation in the form of gametes, each a living unit incapable of producing an individual without intimate association with another produced by the opposite sex.

(2) Association of two gametes of opposite kinds—in which two become yoked together into a zygote, and react upon one another to give rise by a process of cell-division to what we ordinarily term an individual with all its various attributes and properties.

(3) Dissociation when from the generative gland of the double structured zygote, the single structured gametes separate out as germ cells.

The nature of the problem underlying the process of heredity involves the finding out of the relation between gamete and zygote, and between zygote and resulting gametes. It requires the determination of the properties of the zygote represented in the gamete: the method of distribution from the one to the other.

The colour of an animal or of a flower, the shape of a seed, or the pattern on the wings of a moth, are all properties, of zygote and all capable of direct estimation. It is otherwise with the properties of gametes. While the difference between a black and a white fowl is sufficiently obvious, no one by inspection can tell the difference between the egg that will hatch into a black and that which will hatch into a white fowl. Nor from a mass of pollen grains can any one to day pick out those that will produce white from those that will produce colourd flowers. Neverthe-

less, we know that inspite of apparent similarity there must exist fundamental difference, among the gametes, even among those that spring from the same individual. At present our only way of appreciating these differences is to observe the properties of the zygotes which they form. And as it takes two gametes to form a zygote, we are in the position of attempting to decide the properties of two unknowns from one known. Fortunately the problem is not entirely one of simple mathematics. It can be attacked by the experimental method, the method which was first employed by Mendel and about whose conclusions and theory, I would crave your indulgence for a few minutes more.

Gregor Johann Mendel was born in 1822, a son of well-to-do peasants in Austrian Silesia. He became a priest in 1847, and studied Physics and Natural Science at Vienna from 1851 to 1853. Thence he returned to his cloisters and became a teacher in the Realschule at Brunn. He made hybridisation experiments with peas and other plants in the garden of the monastery of which he eventually became abbot. After eight years of patient experimenting, chiefly with the *edible pea* he reached a very important conclusion in regard to the inbreeding of hybrids which is often briefly referred to as "Mendel's Law." His publication was practically buried in the *Proceedings of the Natural History Society of Brunn* in a short paper of some forty pages. It appears that so long as he lived his recorded results were hardly treated with any earnestness, on the otherhand in most quarters he received nothing but sublime contempt,

probably owing to the utter neglect of his work by the scientific world. Mendel gave up his experimental researches during the latter part of his life. His closing years were shadowed with ill health and embittered by a controversy with the Government on a question of the rights of his monastery. He died of Bright's disease in 1884.

In the spring of the year 1900, within a few weeks of each other, the three papers of Hugo de Vries, Correns and Tschermak giving substance of Mendel's long-forgotten treatise, appeared. de Vries called this the "*law of the splitting of hybrids.* Each of these three writers was able from his own experience to confirm Mendel's conclusions and to extend them to other cases. There could, therefore, from the first be no question as to the truth of the facts.

What Mendel sought to discover was the law of inheritance in hybrid varieties, and he chose for experiment as already noticed the edible pea (*Pisum sativum*) among others.

In order to obtain a clear result he saw that it was absolutely necessury—

(i) to start with pure breeding homogeneous materials,

(ii) to consider each character separately,

(iii) on no account to confuse to different generations together, lastly

(iv) he realised that progeny from distinct individuals must be separately recorded.

In studying the different forms of peas of twenty-two varieties, Mendel found that there were seven

differentiating characters which could be relied on, which are :—

1. The colour of the reserve material in the cotyledons—pale yellow, bright yellow, orange, or green ;

2. The form of the ripe seeds, whether roundish, with shallow wrinkles or none, or angular and deeply wrinkled ;

3. The colour of the seed-coats, whether white, as in most peas with white flowers, or grey, grey brown, leather brown, with or without violet spots, and so on ;

4. The form of the ripe pods, whether simply inflated, or constricted, or wrinkled ;

5. The colour of the unripe pods, whether light or dark green, or vividly yellow, this colour being correlated with that of stalk, leaf-veins and blossoms ;

6. The position of the flowers, whether axillary or terminal ;

7. The length of the stem, whether tall or dwarfish.

He chose a number of pairs of contrasted characters and made crosses between varieties differing markedly in respect of one pair of characters investigating one pair of contrasted characters at a time all along the line.

Mendel took a pair of varieties of which one was tall, being 6 to 7 ft. high and the other was dwarf, $\frac{3}{4}$ to $1\frac{1}{2}$ ft. Previous tasting had shown that each variety bred true to its peculiar height. These two were then crossed together. In peas this is an easy

operation. The unbroken anthers can be picked out of a bud with a pair of fine forceps and the pollen chosen may be at once applied to the stigma of an emasculated flower. The cross-bred seeds thus produced grew into plants which were always ***tall***, having a height not sensibly different from that of the pure tall variety. It was found to make no difference which was used as the pollen parent and which was used the ovule parent The result in every case was the same.

From the fact that the character, tallness, appears in the cross-bred to the exclusion of the opposite character, Mendel called it a ***dominant*** character; ***dwarfness*** which disappears in the first filial generation of this particular cross-bred he called ***recessive***. [In recent terminology the first filial generation is called F_1.]

The tall cross-bred so produced in its turn bore seeds by self-fertilisation. These are the next generation, F_2. When grown up they prove to be mixed, many being tall, some being short but ***no intermediates***. Upon counting the members of the F_2 generation it was discovered that the proportion of talls to shorts exhibeted a certain constancy averaging about three talls to one short (*i.e.*, 75% dominants to 25% recessives).

These F_2 plants were again allowed to fertilise themselves and the offspring of each plant was separately shown. It was then found that the offspring F_3, of the recessives consisted entirely of recessives. Further generations bred from these recessives again produced recessives only, and therefore the recessives

which appeared in F_2 are seen to be pure to the recessive character, namely in the case we are considering, to dwarfness.

But the tall (F_2) dominants when tested by a study of their offspring (F_3) instead of being all alike (as the dwarfs of recessives were) proved to be of two kinds viz :—

(*a*) Plants which gave a mixed F_3 consisting of both talls and dwarfs, the proportion showing again an average of three talls to one dwarf and

(*b*) Plants which gave talls only and are thus pure to tallness.

The ratio of the impure (*a*) plants to the pure (*b*) plants was 2 to 1.

The whole F_2 generation therefored formed by self-fertilisation of the original hybird consists of three kinds of plants :—

25%	50%	25%
Pure dominants	Impure dominants	Pure recessives

The results is exactly what would be expected if both male and female germ cells of the cross bred F_1 were in equal numbers, bearers of either the dominant (D) or recessive (R) character, but not both. If this were so, and if the union of the male and female germ cells occurs at random, the result would be an F_2 family made up of

$$\underbrace{25\ DD : 25\ DR : 25\ DR}_{3\ D} : \underset{1\ R}{25\ RR}$$

Mendel experimented with other pairs of contrasted characters and found that in every instance they

followed the same scheme of inheritance. Thus coloured flowers were dominant to white, in the ripe seed yellow was dominant to green, and round shape of seeds to wrinkled, and so on. In every case where the inheritance of an alternative pair of characters was concerned, the effect of the cross in successive generations was to produce three and only three different sorts of individuals, viz., dominants which bred true, dominants which gave both dominant and recessive offspring in the ratio of 3 : 1 and recessives which always bred true.

So far we were thinking about the results obtained when two individuals differing in a single pair of contrasted characters are crossed together; but Mendel also used plants which differed in more than a single pair of differentiating characters. in such cases he found that each pair of contrasted characters followed the same definite rule, but that the inheritance of each pair was absolutely independent of the other.

Thus when a tall plant bearing coloured flowers was crossed with a dwarf plant bearing white flowers the resulting hybrid was a tall plant with coloured flowers. For coloured flowers are dominant to white as tallness is dominant to dwarfness. Now let us consider the cases of the succeeding generation (F_2). In this generation there are plants with coloured flowers and plants with white flowers in the proportion of 3 : 1, and at the same time tall plants and dwarf plants in the same proportion. Hence the chances that a tall plant will have coloured flowers are three times as great as its chances of having white flowers. And this is also true for the dwarf plants. Therefore

in F_2 generation we have four classes of hybrids: coloured talls, white talls, coloured dwarfs and white dwarfs, and we should further expect those four forms to appear in the ratio of 9 coloured talls, 3 white talls; 3 coloured dwarfs and 1 white dwarf. This is a necessary result of the primary conditions that the talls should be to the dwarfs as 3 : 1 and at the same time the coloured flowered should be to the white flowered as 3 : 1. These are the proportions that Mendel found to obtain actually in his experiments. Mendel also pointed out that the principle may be extended indefinitely. If, for example, the parents differ in three pairs of characters A, B, and C, respectively dominant to a, b, and c, the F_1 individuals will be all of the form ABC, while the F_2 generation will consist of 27 ABC, 9 ABc, 9 AbC, 9 aBC, 3 Abc, 3 aBc, 3 abC and 1 abc.

All these results may be summerised into the following statement.

When individuals differing in a number of alternative characters are crossed together, the hybrid generation, provided that the original parents were of pure strains, consists of plants of the same form; but when these (F_1) are bred from, a redistribution of the various characters occurs. That redistribution follows that same defenite rule for each character, and if the constitution of the original parents be known, the number of possible forms and the proportions in which they occur can be readily calculated.

We will now try to state the theoretical aspects of the observed facts already detailed.

Except for the relatively rare instances of parthenogenesis and asexual reproduction (instances of which have been enumerated above on page 7) a new individual whether plant or animal. arises as the joint product of two sexual cells derived from individuals of different sexes. Such sexual cells, whether ovules or ova, spermatozoa or pollen grains, are known by the general term of *gametes*, or marrying cells, and the individual formed by the fusion or yoking together of two gametes is spoken of as a zygote. Since a zygote arises from the yoking together of two seperate gametes, the individual so formed must be regarded throughout its life as a double structure in which the components brought in by each of the gametes remain intimately fused in a form of partnership. But when the zygote in its turn comes to form gametes, the partnership is broken and the process is reversed. The component parts of the dual structure are resolved with the formation of a set of single structures, the gametes.

From the observed facts therefore the life cycle of a species from among the higher plants or animals may be regarded as falling into three periods :—

(1) A period of isolation in the form of gametes, each a living unit incapable of further development without intimate association with another produced by the opposite sex, these are termed germ-plasm-unicelluler organisms living as parasites on the multicellular individual body (somatoplasm).

(2) A period of association in which two gametes become yoked together into a zygote. and react upon one another to give rise by a process of cell division

to what we ordinarily term an individual with all its various attributes and properties. And

(3) A period of dissociation when the single structured gametes separate out from that portion of the double structured zygote which constitutes its generative gland.

The colour of an animal or of a flower, the shape of a seed, or the pattern on the wings of a moth are all zygotic properties, and all capable of direct estimation—but not so the properties of gametes. While the difference between a black and a white fowl is sufficiently obvious, no one by inspection can tell the difference in the egg that will hatch into a black and that which will hatch into a white. Nevertheless, we know that in spite of apparent similarity there must exist fundamental difference among the gametes, even among those that spring from the same individual. At present our only way of finding out those differences is to observe the properties of the zygotes which they form. As two gametes go to form one zygote, we have to find out the properties of two unknowns from one known. The problem, however, is not entirely one of simple mathematics but the solution has to be effected by the experimental method.

Mendel determined a general scheme of inheritance based on those seven pairs of alternative characters and provided a theoretical interpretation of that scheme in terms of germ cells. This theoretical interpretation with all that have been deduced from that interpretation is now known as Mendelism. He

conceived of the gametes as bearers of something capable of giving rise to the characters of the plant, but he regarded any individual gamete as being able to carry one and one only of any alternative pair of characters. One particular gamete could carry tallness or dwarfness but not both. The two were mutually exclusive so far as the gamete was concerned. It must be pure for one or the other of such a pair, and this conception of the purity of the gametes is the most essential part of Mendel's theory. In the gamete therefore there is either a definite something corresponding to the *dominant* character or a definite something corresponding to the *recessive* character—the essential condition of the theory is that these somethings, whatever they are, could not co-exist in any single gamete. For those somethings the term *factor* is now being applied. The factor then is what corresponds in the gamete to the *unit character* that appears in some shape or other in the development of the zygote. Tallness in the pea is a unit-character and the gametes in which it is represented are said to contain the *factor* for tallness. Let us try to deduce the results that should follow from Mendel's conception of the nature of the gametes. All the gametes whether ovules or pollen grains in the original tall plant must bear the *tall factor*—because the parent plant bred true. Similarly all the gametes—(whether pollen grains or ovules) of the original dwarf plant must bear the *dwarf factor.* A cross between these two means the union of a gamete containing tallness with one bearing dwarfness. Owing to the completely dominant nature of

the tall character such a plant is in appearance indistinguishable from the pure tall, but it differs markedly from it in the nature of the gametes to which it gives rise. When the formation of the gametes occurs, the elements representing dwarfness and tallness *segregate* from one another, so that half of the gametes produced contain the one, and half contain the other of these elements. For on hypothesis every gamete must be pure for one or other of these factors. This is true both for the ovules as well as the pollen grains. It is very easy to calculate what should happen when such a series of pollen grains meet such a series of ovules. The result precisely agrees with the number obtained by experiment, and the close accord of the experimental results with those deduced on the assumption of the purity of the gametes as enunciated by Mendel affords the strongest of arguments for regarding the nature of the gametes and their relation with characters of the zygotes in the way that he has done.

Bateson was the first to demonstrate the application of Mendelian principles to animals and a host of biologists have followed them up. Among animals the coat-colour for animals, the form of the feathers and of the comb in poultry, the waltzing habit of Japanese mice, and eye colour in man are but a few examples of the diversity of character which all follow the same law of transmission. There had been however cases which at first seemed to fall without the scheme, but gradually by the light of further knowledge all these had been brought strictly to agree with the scheme of inheritance above stated.

We now propose to consider one or two cases of experiments where apparent difficulties were met with and the way in which these difficulties have been explained.

Many of the different breeds of poultry are characterised by a peculiar form of combs, such as rose-comb, pea-comb, single-comb and walnut-comb. It was shown that the rose-comb with its flattened papillated upper surface and backwardly projecting pike was dominant in the ordinary way to the deeply serrated high single-comb which is characteristic of Chutiānagpur forest-fowls as well as another breed. Experiment also showed that the pea-comb, a form with a low central and two well-developed lateral ridges such as is found in Indian game, behaves as a simple dominant to the single-comb. The interesting question arose as to what would happen when the rose and the pea, two forms each dominant to the same third form, were mated together. It seemed reasonable to suppose that things which were alternative to the same thing would be alternative to each other, that is either rose-comb or pea-comb would dominate in the hybrid, that F_2 generation would consist of dominants and recessives in the ratio 3 : 1. The result of the experiment was however very different. The cross bred fowl of rose-comb was endowed with comb quite unlike either of them and resembled somewhat of the shape of a half of a walnut called walnut-comb. This is a type of comb which is normally characteristic of the Malay fowl. Then again when these F_1 birds were bred together, a further unlooked-for result was obtained. As was expected there appeared in the

F_2 generation the three forms walnut, rose and pea, but there also appeared a definite proportion of single-combed birds, and among many hundred of chicken bred in this way the proportion in which these four forms: walnut, rose, pea and single appeared was 9 : 3 : 3 : 1. This exactly is the ratio found in F_2 generation where the original parents differ in two pairs of alternative characters. Without entering into any detailed explanation of these interesting cases it may be here stated that the original wild stock of fowl of India from which all the domesticated fowls, have been derived--happens to possess a single comb.

Medelism thus also provides an excellent explanation for the well known but puzzling phenomenon *reversion* or *atavism* (=falling back to a prototype).

The cross between the black mouse or the black rabbit and the white mouse or the white rabbit in certain instances results in a complete reversion to the wild grey form. Expressed in Mendelian terms, the production of the grey form was a necessary consequence of the meeting of the factors in the same zygote. As soon as they are brought together, no matter in what way the reversion is bound to occur. Reversion, therefore, in such cases should be regarded as the bringing together of complementary factors which had somehow in the course of evolution become separated from one another. In some cases it is found by careful breeding that the nature of the reversion is very much complicated owing to a large number of factors. Another similar but a little complicated case may be considered. The Himalayan rabbit is a well-known breed. In appearance it is a white rabbit

with pink eyes, but the ears, paws, and nose are black. The Dutch rabbit is another well-known breed, the anterior portion of the body of which is white and the posterior part coloured, the eyes are surrounded by coloured patches extending up to the ears, which are entirely coloured. By crossing a Dutch rabbit with a Himalayan, the F_1 generation was found to be reversion to the wild grey colour; on breeding from the F_1 generation a series of coloured forms appeared in the proportion of 9 wild grey, 3 blacks, 3 yellows and 1 tortoise shell. The cases need not be multiplied. It is interesting to note in cases where pedigree is well known that these principles appear to hold good with respect to crosses between the darkly pigmented Eastern races and the White. The diagram on the wall represents pedigree of a family in which one parent belonged to a darkly pigmented Eastern race (a Hindu) and the other an English white. Segregation seems to have occurred in subsequent generations. The family had resided in England for several generations therefore in this particular case there was no chance for a further admixture of dark coloured factors. Most noticeable is the family produced by a very dark lady who had married a white man. Some of the children were intermediate in colour, but two were fair whites and two were dark like Hindus. This sharp segregation or splitting out of darks and whites in addition to intermediates strongly suggests that the nature of the inheritance is Mendelian, though it appears to be complicated by the existence of several factors which may also react upon one another.

We will now say a few words about *mutation.* A decade before the close of the sixteenth century (1590), Sprenger, an apothecary of Heidelberg, found in his garden a peculiar form of Greater Celandine *(Chelidonium majus).* It was marked by having its leaves cut into narrow lobes with almost linear tips, and having the petals also cut out. This sharply defined new form suddenly appeared among the plants of *C. majus* which the apothecary had cultivated for many years. It was recognised by botanists as something quite new. It was not to be found wild, or any where except in the Heidelberg Garden but from the first this new cut-leaved Celandine bred true from seed.

Hugo de Vries of Holland began hunting about around Amsterdam for a plant which would show hints of being in what we may call a changeful mood like the case of Greater Celandine just mentioned. In the course of his wanderings around Amsterdam, in 1886 de Vries came across a deserted potato-field at Hilversum—a field of treasures for him. For there he found his long-looked-for plant an Evening Primrose *(Œnothera lamarckiana)* in the changeful mood. Its chief interest was its changefulness. Almost all its organs were varying as if swayed by a restless tide of life. The next chapter in the famous investigation began with a transference of the new forms and the parent stock from the potato-field of Hilversum to the Botanical Garden at Amsterdam. From each of his three samples there arose several distinct groups, which if they had been found in nature would have been reckoned as distinct species of Evening Prim-

rose. He hailed these as new elementary species and he applied one of the crucical tests of specific rank, and found they bred true. In short de Vries thought he had found a plant in process of evolution and the most interesting feature was the apparent abruptness in the origin of the new forms. They seemed to arise by leaps and bounds, by organic jerks; they illustrated what de Vries has called "*mutation*."

These sports, to use Darwin's term for them or "*mutations*" as they have been called by de Vries, are now considered to be due to a disturbance in the process of cell-division through which the gametes originate. At some stage or other the normal equal distribution of the various *factors* is upset, and some of the gametes receive a *factor* less than others. From the union of two such gametes, provided that they are still capable of fertilisation, comes the zygote which in course of growth develops the new character. Until the production of *mutations* can be induced by experiments it would not be possible to understand the conditions which govern their formation.

It is however necessary here to emphasize the fact, that provided the constitution of the gametes is unchanged, the heredity of such variation is independent of any change in the conditions of nutrition or environment which may operate upon the individual producing the gametes.

An individual organism, whether plant or animal, reacts, and often reacts markedly, to the environmental conditions under which life is passed. These effects are best seen in the modification of size and

weight. Plenty of sunlight or a richer soil may mean stronger growth in a plant, better nutrition may result in a finer animal, superior education may lead to more intelligent man. But although the changed conditions produce a direct effect upon the individual, there is not a single *scientifically tested* evidence that such alterations are connected with any alterations in the nature of the gametes which the individual produces. Without such modifications of the gametes these effects cannot be perpetuated through heredity, but the conditions which produce the effect must always be renewed in each successive generation.

The variations should be thus distinguished into two kinds with reference to the mode of origin. Those which are due to the presence of specific factors in the gemetes of the organism and those which are due to the direct effect of the environment during its life time. The former are now known as *mutations* which Darwin designated as "sports"; these are found to be inherited according to the Mendelian Scheme; the latter have been termed *fluctuations* and there is no valid reason for supposing that they are ever inherited. The cases in which the effects produced during life time of the individual appear to affect the offspring, are not due to heredity. Whenever, as in seed-plants and mammals, the organism is parasitic upon the mother during its earlier stages the state of nutrition of the latter will almost certainly react upon it, and in this way a semblance of transmitted weakness or vigour is brought about. Such a connection between mother and offspring is purely

one of environment, and has nothing to do with the ordinary process of heredity.

As Darwin very clearly established, any theory of Evolution must be based upon the facts of heredity and variation. Evolution is only possible through the survival of certain variations and the elimination of others. For this, a variation must be inherited; and to be inherited it must be represented in the gametes. This is the case only for those variations which have been termed *mutations*. As to the other kind of variations, those that are the result of the direct action of the environment upon the individual, and are called *fluctuations*, there is no evidence of inheritance. Thus these fluctuations cannot play any part in the production of that succession of temporarily stable forms which is termed Evolution. Therefore the mutation is now regarded as the basis of Evolution—as the material upon which Natural Selection works, and these heritable and discontinuous variations are in the main the outward manifestation of the presence or absence of corresponding Mendelian factors.

Thus there is nothing in the Mendelian discovery nor in the Theory of Mutation as established by de Vries, that runs counter to the cardinal doctrine that species have arisen "by means of Natural Selection, or The preservation of favourd races in the struggle for *life" to use the definition of that doctrine inscribed on* the title of the *Origin Of Species.*

It is of course evident that process of natural selection now established is in some respects at variance with that generally held during the last half of the nineteenth century.

It was assured, in the first place, that variation was a continuous process, and, secondly, that any variation could be transmitted to the offspring. Both these assumptions have since been shown to be unjustified.

It was assumed that any variation, however small, might have a selection value, that is to say could be transmitted to the offspring. The process was therefore supposed to be a cumulative one. The slightest variation in a favourable direction would give natural selection a starting-point to work on. It has been already shown that the individual variations (fluctuations) are not heritable and therefore cannot be operated on by the process of natural selection.

Heritable variation has a definite basis in the gamete, and it is to the gamete, therefore, and not to the individual that we must look for the initiation of this process. In the course of the production of the gamete some factor some how is added or removed from the gamete upon that removal or addition the new variation owes its existence. The new variation springs to being by a sudden step, not by a process of gradual and almost imperceptible augmentation. It is not continuous but discontinuous, because it is based upon the presence or absence of some definite factor or factors, upon discontinuity in the gamete from which it springs. Once formed, its continued existence is subject to the arbitrament of Natural Selection. If it is of value in the struggle for existence, Natural Selection will decide that those who possess it shall have a better chance of survival and of leaving offspring than those who do not possess it. If it is harmful to the individual, Natural Selection will soon

bring about its elimination. But if the new variation is neither harmful nor useful there seems to be no reason why it should not persist.

In this way a very great difficulty that beset the older view is avoided. For on the older view no new character could be developed except by the piling up of minute variations through the action of Natural Selection. Consequently any character found in animals and plants must be supposed to be of some definite use to the individual. Otherwise it could not have developed through the action of Natural Selection. But there are plenty of characters to which it is exceedingly difficult to ascribe any utility, at least in the small begining, and the ingenuity of the supporters of this view has often been severely taxed to account for their existence. For instance—to account for the evolution of electric organs in fishes, or the musical and similar co-lateral facaulties in man. On the present view this difficulty is avoided. The origin of a new variation is independent of Natural Selection, and provided that it is not directly harmful, there is no reason why it should not persist. In this way the holders of the Theory of Natural Selection are released from the burden of discovering an utilitarian motive behind all the multitudinous characters of living organisms. Because it is now very definitely recognised that ***the function of Natural Selection is selection and not creation.*** The Natural Selection has nothing to do with the formation of the new variation. Natural Selection only decides whether any particular variation is to survive or to be eliminated.

It is well known that in earlier years Darwin himself was inclined to ascribe more importance to "sports" as opposed to continuous minute variation, and to consider that they might play a not inconsiderable part in the formation of new varieties in nature. This view, however he gave up later, because he thought that the relatively rare sports (mutations) of the present would rapidly disappear through the swamping effects of crossing with more abundant normal forms, and so, even though favoured by Natural Selection, a sport would never succeed in establishing itself. Mendel's discovery has eliminated this difficulty. Because the sport may differ from the normal in the loss of a factor and may therefore be recessive to it. When mated with the normal this character would seem to disappear in F_1 generation though, of course, half of the gametes of its progeny would bear it. By continual crossing with normals a small proportion of heterozygotes would eventually be scattered among the population, and as soon as any two of these would mate together the recessive sport would appear in one quarter of their offsprings (F_2 generation) which would breed true.

A population containing a very small proportion of dominants and one containing a similar proportion of recessives are equally stable. The term dominant is in some respects apt to be misleading, for a dominant character cannot in virtue of its dominance establish itself at the expense of a recessive one. Brown eyes in man are dominant to blue, but there is no reason to suppose that as years go on the population of the world will become increasingly brown-eyed. If the

conditions are equal both are on an equal footing. If however either dominant or recessive be favoured by Selection the conditions are altered, and it can be shown that even a small advantage possessed by the one will rapidly lead to the elimination of the other. Even with a five percent selection-advantage in its favour it can be shown that a rare sport will oust the normal form in a few hundred generations In this way we are freed from a difficulty inherent in the older view that varieties arose through a long continued process involving the accumulation of very slight variations. On that view the establishment of a new type was of necessity a very long and tedious process involving many thousand generations. For this reason the biologist had been accustomed to demand a very large supply of time often a great deal more than the physicist was disposed to grant, and this had sometimes led him to expostulate with the physicist for cutting off the supply. On the newer views, however, this difficulty need not arise for it is now realised that origin and establishing of a new form may be a very much more rapid process than has hitherto been deemed possible.

There are two new branches of experimental studies which have come into existence out of Mendelism—pursuits which have been possible as the results of Mendelian discoveries—I mean the studies of Genetics and Engenics: words which for their similarity of origin we are sometimes apt to confuse.

Genetics is the term applied to the experimental study of heredity and the main concern of its students

is the establishing of law and order among the phenomena there encountered.

Eugenics, on the other hand, deals with the improvement of the human race under existing conditions of law and sentiment.

These definitions will give us some ideas as what vast field of researches Mendelism has opened up and what extended practical application it is likely to command

I shall now conclude with a few remarks about ourselves. Mankind consists of a single species, in which several distinct groups termed *races* are recognised which breed true. They all belong to the same species as it is found that no two *races* are so distinct, that when they are crossed, sterile progenies are produced.

As to how and when man emerged from the terrestrial animal population is a matter which need not be discussed here. It is not improbable that it was in the remote period known as the lower Miocene about which time it came to happen.

The leading feature in the development and seperation of man from amongst other animals is undoubtedly the relatively enormous size of the brain in man and the corresponding increase in the activities and in the capacity of the brain substance. In this it succeeded but at the sacrifice of the gift of heritable instinct.

The increased bulk of the cerebral substance means increased educability, that is an increased power of storing up *individual experiences* which tends to take

the place of the inherited mechanism which is the basis of *instinct* (inherited memory of the species). The loss of instict in man is compensated by its susceptibility to enormous individual educability or in otherwords in order to make the brain capable of enormous individual development it had to give up the power of inheriting the fixed inborn knowledge. This *educability* in order to be effective is accompanied by an intense desire for knowledge which is the main spring for "why and how" of infancy and the devouring appetite for tradition and racial history in childhood. The love for fairy-tales of children and the thirst for novel reading in youth may be only instances of degeneration of the same most essential natural craving of the species. On the other hand the nature to fulfil this function had to make the old age garrulous: anxious to exhaust the stock of its long experience for the benefit of the young and the coming generation before it has to run out its short span. We will have to refer presently to this all important love for learning and imparting the lore of tradition of the species in connection with the effect of crosses among the different races.

As individuals, primitive men were probably more than a match for us physically, and at least our equals mentally. It is very difficulty to say who was a greater man of the two, he who invented the art of producing fire artificially or he who invented the steam engine.

According to Prof. Osborn physically as well as intellectually men of to-day are not a bit superior to the men of twenty thousand years ago. All the progress and the advantage we have over those remote

ancestors lie in the accumulated experience of the human race since then.

We are "heirs of all the ages" not biologically but only culturally. "Standing on the shoulders of the last generations we see further because we are higher up, not because we are taller."

The races breeding true, have mutally independent and distinct developmental history of culture and civilization. It is desirable that each race should have the fullest intercourse with every other in commerce and in the exchange of ideas. This is mutually beneficial to all, but the obliteration of all racial differences may not be advantageous to the individual. Human racial crossing in general therefore is a risky experiment, because it interferes with social inheritance, which after all is the chief asset of civilisation. Main advantage which we have over our primitive ancestors, lies in the accumulated experiences of the respective race-traditions since the begining. Because all these we learn as individuals from our mothers and fathers or in the schools, in the places of devotion and worship, in the markets or in the courts of justice. Wide racial crosses thus unsettle the formations of these agencies of enlightment. Of course it is true that the offsprings produced by crossing widely divergent races do not necessarily lack in vigour, size or reproductive capacity. But we must remember that mating out of the race, when mates within the race are available, in a manner proves that the individual so mating is a social outcast. It is not therefore surprising that progenies of such individual are often feeble.

The distinct races are believed to be sufficiently

diversified among themselves to allow the maximum benefit from intercrossing without resorting to crosses with widely divergent branches of the human family. Racial crosses however if so conducted as not to interfere with social inheritance, may be expected to produce on the whole inter-mediates as regards physical and psychic characters.

Our knowledge of human heredity is less accurate than of animal and plants because here we are debarred from experiments. There have been collection of data and attempts to analyze them in very compresive scale both in England and in America. In England it is being done at the Eugenic Laboratory of the University of London founded by Galton and presided over by Karl Pearson and in America at the Eugenic Record Office Cold Spring Harbour, New York directed by C. B. Davenport. Unfortunately for the cause of science Pearson has shown a distinct prejudice against Medelism while in the American attempt the workers are tought in advance to regard all inheritance as Mendelian. Thus while these prejudices and bias do not impair the value of the data so carefully collected, they however shake ones confidence in their analysis. Calcutta is exceptionally a most convenient centre for collection of data about human inheritance. I hope it is not too much to expect that some of our youngmen will take up the work and initiate a centre of study attached to this national institution, nor do I think it would be too much to expect that some of our cultured and patriotic millionaires would come forward to help this most deserving institution to open and maintain such an additional department.

Some Practical Hints to Improve the Dietary of the Bengalis.

By

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Rasayanacharya.

I do not claim any originality in this paper, but the importance of the subject and the lack of interest shown by people whom it most concerns are my sufficient excuse for bringing this matter up for discussion before this learned assembly.

There have been very few investigations based on scientific method regarding the dietary of the Bengalis. But whenever any attempt has been made in this direction, the dietary has been found to be wanting in *proteid* or *muscle-forming constituent*, and over-rich in *carbo-hydrate elements* (starch and sugar). The proportion of fat, except in the case of the well-to-do people, is also generally deficient. The latest investigation into the dietary of Bengali students by Major D. McCay, I.M.S., points to great deficiency of *proteids* in their diet, and to this cause, Major McCay ascribes the poor physique and the feeble staying power of the Bengali youths.

Now, as the growth, development and capacity for work of an individual, as well as the health and vigour of a community, depend on the supply of food of the proper quantity and quality, it is of the utmost national importance that greater attention should be

given to this subject, specially in view of the changed and changing economic conditions of the people.

The subject is not without its difficulty and complexity. Diversity of race and creed, religious sentiments, habits and traditions, and the economic conditions of the people—all have their bearing on the consideration of this problem ; and the selection of a dietary, therefore, which will be acceptable to the people in general, as not going against their cherished notions, and at the same time, being well within the easy reach of everybody, is a matter of careful thought and judgment. And the matter of prime consideration is that such a dietary must contain all the various nutritive constituents of food, viz., proteids, fats, carbo-hydrates and salts in sufficient quantity and in proper proportions, for the growth of the body, repair of waste, supply of energy for work and maintenance of health.

I propose to consider this question briefly from the above points of view.

The dietary of a Bengali Hindu of the *bhadralog* class consists usually of rice, *dal*, fish, vegetables, ghee, mustard oil, milk (or one or other of its various preparations) and sweets, supplemented now and then by a small allowance of fresh fruits varying according to seasons. In towns, rice has partially been supplanted in recent times by wheat flour, specially in the evening meals, made into *rootis* or *loochis* ; but students living in hostels and messes in Calcutta do not get it. In villages and among the labouring classes, rice still forms the principal food, for both morning and evening meals. There are a great many varieties of rice grown

and consumed in this Province. They are generally of equal nutritive value, the *atap* (sun-dried) and the *balam* being, however, slightly richer in proteid than the other varieties. Rice is much poorer in proteid than wheat, barley, oats, *makai* (Indian corn), etc., which are used as its substitutes in other parts of India (except Orissa and Madras). The average percentage of proteid in rice is 5 ; it is over 10 percent in wheat, barley, *makai* and oats. Rice is also very poor in fat, but it is very rich in starch, and the rice-starch is the most easily digestible of all known starches. The average time taken by boiled rice for complete digestion is about one hour only.

As rice is so very deficient both in proteid and fat, it is of the utmost importance that it should be supplemented by food-stuffs which contain these two constituents in rich proportions. The mistake our people generally make is to take a large quantity of rice (which for the time being appeases the appetite) with small quantities of other foods rich in proteids and fats. The result is that we get fattened (for it is the excess of starch and not so much any excess of fat actually taken in that food that causes deposition of fat in the body), the belly becomes bulging, the muscles become flabby and wanting in tone, strength and activity, and the countenance becomes somewhat sallow and dull.

I have already mentioned that the marked defect in the dietary of the ordinary Bengali Hindu is insufficiency of the proteid and fat elements in it. It will be my endeavour to show how best this deficiency can be made up. To start with, we must remember that

most authorities on food are agreed that at least 80 grammes (1235 grains) of proteids are daily required *for an adult engaged in the ordinary duties of life. A careful examination, however, of the average* daily diet of a Bengali Hindu reveals the fact that not more than 50 grammes of proteid are available to an adult Bengali in the dietary that usually obtains in his household. In the case of children, this deficiency is even more marked. The Bengali mother has a great partiality for rice and much dread against *dal*, and if her child takes a large quantity of rice with the help of a little fish-soup (the fish forming a negligible ingredient in the latter dish) and finishes the meal with a little milk and brown sugar, she is well satisfied. Such a dietary is, however, most unsuitable for young people in the growing period of their life when proteid is most wanted, not only to help the growth of the body but also to repair the great tissue-waste caused by the ceaseless activities of young life.

The only way to remedy this defect is by taking less quantity of rice and consuming larger quantities of foodstuffs that are rich in proteids and fats. Among foodstuffs which contain the largest proportion of proteids, the most common are meat, fish, eggs, milk and various kinds of pulses *(dal).* Meat, on an average, contains 20 percent of proteids, fish 18 percent, eggs 14 percent, milk 4 percent and *dal* about 24 percent. We must make our choice of any of these five articles to make up the deficiency of proteid in rice. Meat is not only rich in proteid but it is also agreeable to the palate; it is, therefore, that we see that except in certain communities in India, people all

over the world who can afford to have it, show a partiality for this food. Moreover, meat is a stimulating food, more stimulating than either fish or *dal* and is, therefore, much liked. [It is, however, a costly food, and the average Bengali cannot afford to have it included in the daily dietary of his family,] unless it is taken in the form of some cheap variety which, however, is a forbidden food to the Hindu. If his requirement is a *seer* of mutton or goat's flesh daily for the family, it means an expense to him of twelve annas per day, which very few people of the ordinary middle class are able to bear, not to speak of the labourers, cultivators or artisans. While, therefore, the introduction of meat into the daily dietary of the Bengalis will undoubtedly tend to improve it—as a matter of fact, it has already been introduced into the dietary of the well-to-do classes—this innovation on a consideration of all the circumstances, seems to me to be inexpedient and impracticable in the case of the vast majority of the Bengali Hindus. Besides, there are a considerable number of people belonging to that community, more specially the women-folk, who would, on no account and under no circumstances, take meat. [Meat cannot, therefore, ordinarily take its place in the Bengali dietary to make up for the deficiency of proteid.]

[We next come to fish,] which is one of the commonest articles of diet in Bengal and is nearly as rich in proteid as meat. It has the great advantage over butcher's meat in being more easily digestible, less constipating, and less stimulating which makes it specially suitable in the case of the young people whose diet should be most nourishing but at the same

time, least stimulating. There are some fish which contain much fat (oil), such as *Hilsa*. These are somewhat difficult to digest. There are others which are poor in fat, such as *Koi*, *Magoor* and *Singhee*; these are easily digestible, and therefore, sit better on weak stomachs and form an excellent invalid diet. The best fish from all points of view are the *Rohi*, *Katla*, *Bhetki*, *Bhangon*, *Parse*, and a few others; these are rich in proteids, contain moderate quantities of fat, are agreeable to the palate, and no wonder they are largely consumed in Bengal. *Chingri* (lobsters and prawns) is no fish at all; it is palatable but difficult to digest and often brings on gastric troubles.

There was a time when every Bengali, rich or poor, used to get plenty of fish with his meals and then his dietary was not defective either in proteid or in fat. I remember, in our younger days, good *Rohi* fish used to be sold in Calcutta at four annas a seer, and other kinds of fish could be had at a much less cost. In the mufussil, the usual price was 2 annas per seer. But fish has become a very costly article now-a-days, not only in towns but also in villages in West Bengal. The state of things is much better in East Bengal where plenty of this important foodstuff, either fresh or in the salted and dry condition, can still be had at a small cost. Good fish ordinarily sells at twelve annas a seer in this town and the price often goes as high up as a rupee. In places around Calcutta, the price is very often not lower, and sometimes it cannot even be had either for love or for money. To a Bengali, whether rich or poor, a little fish is indispensable in his daily diet. The ordinary householder cannot afford

to buy more than half a pound of fish a day for the whole family which usually consists of not less than six ; this would give only three quarter of a chittack (one and a half ounces) of fish per head. The bones, the scales and the entrails, constituting as they do about 50 percent of the fish as bought from the market, would further reduce the share of each individual by nearly half in the prepared fish. Remembering also that fish contains as much as 78 percent of water, we see that what each member of the family ultimately gets is only an apology for fish in his daily meals which gives him very little proteid to make up the deficiency in his rice-diet. The only fair average allowance of fish for an individual (where no meat is taken) would be a quantity not less than 3 chittaks (6 ounces) per day. Thus, if the family consist of 6 members, the daily consumption of fish would come to about 1¼ seers which would mean an expense of at least a rupee on this head only and this, I am afraid, very few people in ordinary circumstances can afford to spend.

The state of things being different in Eastern Bengal where fish is to be had cheaply, people over there enjoy much better health ; their average stature is generally higher, the make and the muscles of their body stronger, they are capable of doing greater amount of labour and enduring greater fatigue than their brethren of Western Bengal.

Egg is an excellent article of food, rich in proteid and fat, and should, whenever possible, be introduced into the diet of our young men.* Duck's egg contains

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* Eggs are admirably adapted chemically to supplement a food rich in carbohydrate, moderately rich in proteid but poor in fat. Such a diet is found in rice and many cereals, and the addition of eggs to these in the form of puddings makes a complete food. " *Hutchinson*,

about 13.5 percent of proteid and about 14 percent of fat; it is, however, a costly food and its price has more than doubled within recent years. Besides, eggs are not liked by many people and there is objection to the use of hen's eggs (or even duck's eggs) on religious grounds. Hindu women do not generally take eggs.

[Milk is rightly considered to be a perfect food, as it contains all the nutritive constituents in such proportions as are necessary for the maintenance of health and growth of young children.* It is rich in proteid, fat and carbohydrate (sugar), but the excess of water (about 87%) it contains makes it unsuitable for use by adults on an extensive scale.] Moreover, in Calcutta and in other large towns, it is as much a forbidden article of food as meat or fish on account of its dearness. Pure milk is obtainable only with difficulty in the large towns of Bengal and its price keeps it out of reach of people of moderate means. [It is an indispensable article of food for children, but those of middle class families seldom get it in sufficient quantity, and, therefore, suffer in growth and development.] There was a time when milk used to be sold pure and cheap in Calcutta, and the poor people could count upon its forming part of their daily meal. The Hindus generally are very fond of milk and they would consider their meal incomplete unless it is supple-

* "It has been found that the casein of milk is the best absorbed of proteids and the fat of milk enters the blood quite as readily as the fat of meat."

"Milk seems to exercise a restraining influence upon putrefactive processes in the intestine."

"As an article of diet in disease, milk occupies a unique position. No single food is of so much value." *Hutchinson.*

mented by, however small a quantity of, milk or one of its various preparations like *dahi*, butter, *khir* (thickened milk), *chhana* (fresh milk-curd) or any sweetmeat prepared from it, such as *sandesh*, etc. Rich people can afford to take, as they do, one or more of the above articles (often to excess) regularly with their daily ls; those among them who are used to plenty of work or physical exercise seem to be all the better for it, but in the case of men of indolent habits, the consequence becomes apparent in their growing fat and their bodies becoming unwieldy and useless for any active work. The poor people, however, have to remain generally satisfied with a small quantity of *dahi* (sour milk,) which is the cheapest of all milk preparations, and as it contains about 4.5 percent of proteid and a good amount of fat, it makes up to a small extent the deficiency of these constituents in the rice-diet.

If meat, fish or eggs cannot be had in sufficient quantity and if milk cannot generally find a place in the Bengali dietary, what should we look to to make up the deficiency of proteid in our dietary? It appears to me that there is only one article of food to fall back upon, which, while cheap and growing in plenty, is richer in proteid than either meat, fish, eggs or milk, which is free from impurities and disease-producing germs, and which, as it were, by instinct has been chosen as one of the principal articles of diet by both the meat-eating and meat-eschewing people of India from time immemorial. This is *dal* (pulses) of various kinds, which, weight per weight, contains more proteid than either meat of fish. Fish, as I have

said, contains about 78 percent of water and on an average, about 50 percent of the stuff as bought in the market is waste in the form of bones and other refuse-matters. [*Dal* contains about 12 percent of water only and in *dal*, you have nothing to reject, and so you get the full value of your good money by its purchase. It no doubt contains less fat than meat or fish, but it is rich in both proteid and starch.] *Dal* is less stimultaing than meat or fish, and being a dry substance, it does not undergo deterioration by keeping. Meat or fish cannot be kept for more than 12 hours in this country without perishing or deteriorating in quality. A seer of *dal* of good quality would cost you not more than two and half annas, whereas the cost of a seer of meat would be about twelve annas. What a difference in the relation of value of the two articles!*

The objections generally urged against the use of *dal* are :—

(1) That it is much less digestible than meat and much proteid in it is lost by non-absorption.

(2) That it is deficient in fat.

(3) That a daily diet of *dal* is monotonous.

I shall briefly consider these objections one by one.

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*"The Edinburgh investigators were of opinion that in order to improve the dietary of the labouring classes, the following principles should be instilled into them :—

1. That a diet of tea and bread or of tea, bread and butter is faulty.

2. That the faults of the tea and bread diet can be corrected by the free use of meat, eggs or other animal food, but that this mode of correction is expensive.

3. That the faults can also be corrected by the free use of oatmeal with milk or *by peas or beans, without extra cost.*" *Hutchinson.*

(1) Habit is a great factor in the assimilation of food. With Europeans who are unaccustomed to eating *dal*, it is quite possible that meat would agree much better than *dal*. But people, who are used to taking *dal* as the Indians are, ought to have no difficulty in digesting it. The average time taken by meat for complete digestion is 3 hours, and *dal*, if properly cooked, would take about the same time. The reason why some people find it difficult to digest *dal* is because, as ordinarily prepared in our homes, *dal* is not properly cooked. The cooked *dal* should never have separate grains visible to the eye, and on being allowed to stand, should never show the watery portion distinct or separate from the substance itself. It should be of a uniform consistence and moderately thick; the grains should be thoroughly done up by prolonged boiling and vigorous stirring. *Dal* prepared in this way (i.e., in fine division) is easily digestible and nearly the whole of its proteid (about 92 per cent) is absorbed into the system.* It is thus inferior to meat by 5 per cent only in respect of absorption. The people of Upper India cook *dal* much better than the Bengalis. They eat it in larger quantity and experience no difficulty in digesting it. In fact, many of the high caste Hindus over there do not touch meat or fish, but depend entirely on *dal*, *rootee* and milk or

* "If properly prepared, the pulses (various forms of *dal*) are absorbed into the intestine very thoroughly. Thus the proteid of pea or lentil (*masoor*) is all taken up except about 8 or 9 per cent when 200 grammes (7 ounces) are given daily. The proteid of pulses, *if given in a fine division*, is capable of very good absorption, considerably better than gluten (proteid of bread) when taken in the form of white bread."—*Hutchinson on Food and Dietetics.*

one or other of its products for the necessary supply of proteid in their food. Our ladies would do well to see that *dal* is properly cooked and well-prepared. They will then find that it would sit kindly on the stomach of their children and would be tolerated by them in larger quantities which they require in the growing period of their life.

The average absorption of proteid of *dal* as ordinarily prepared is 80 per cent and of meat 97 per cent. But if *dal* is in a fine state of division, there is 10 or 12 per cent additional absorption, and this should always be borne in mind in preparing this dish in our houses. And this loss by non-absorption of 10 per cent is more than compensated by its cheapness. Besides, when meat forms the principal food, there are very few people who do not take it in excess, thus taking sometimes three or four times more proteid than what is needed by the system. And is not this excess quantity wholly wasted? And is it not a much more serious waste on both economic and physiological considerations? The elimination of the unabsorbed proteid of *dal* is after all a simple matter; it is only a mechanical process. But the excess of proteid of meat absorbed in the body not only puts a very severe strain on the organs of elimination, but the uneliminated portion is the root-cause of many serious constitutional disorders. The ten per cent loss of proteid in *dal* by non-absorption is, therefore, a matter of much less consequence than the retention of excess of absorbed meat in the system.

(2) The second objection urged against *dal*, viz., that it contains very little fat, is no doubt well-founded.

Indeed, *dal* does not contain more than 2 per cent of fat, whereas in meat, the average percentage of fat is 5. But this defect is made good, as is usually done in our household, by adding a quantity of oil (or *ghee* if one can afford to do it) to the *dal* during the process of preparation. This is a matter of common knowledge to any cook worthy of his hire, and thus people ignorant of the scientific principles of dietary, never cook their *dal* without adding some oil or *ghee* to it.

(3) The third objection that a daily diet of *dal* is monotonous scarcely holds good if we know only how to make its various preparations. *Dal* could be taken in so many different ways and forms that, instead of becoming monotonous, it can be made into some of the most tempting dishes in our daily dietary. Of course, if one takes it day after day in one form only, *e.g.*, as boiled *dal*, it loses its attractiveness and no wonder one would soon get tired of it. But none knows better than the Bengali housewife of the old school how this one article of diet could be turned into a variety of attractive dishes so tempting to the children and to whose charms, even older people are not insensible. At one time, it was considered to be an accomplishment, not to say a useful occupation, for the ladies of respectable families to know how to make the various kinds of *burrees* from *dal* by the process of the sun's heat. These enter into the composition of a large number of dainty dishes which are as nourishing to the body as they are agreeable to the palate. But times are changed. The ladies of the new school of thought would hardly care to learn, even if they have the leisure to do so, the very many

niceties of art that are involved in the successful making of even one variety of those delightful preparations of which their grandmothers knew by hundreds, and as a consequence, the art of cooking attractive vegetarian dishes has almost become an unknown thing in the Bengali homes.

[Then again, how many kinds of dainty cakes and sweetmeats could be prepared from the different varieties of *dal*! The combination of the nutrient constituents of food in some of these preparations is almost faultless. To mention a few only, e.g., *Kachoo rees*, *Dalpurees*, the inimitable *Pithas* of the *Pous Parvan*, the *Dhoka*, the *Dalmoot*, the *Jhoories*, the *Bhajis* (vegetables with a coating of *dal*-paste fried in *ghee* or oil), the *Papars*, the *Ras-burrhas*, *Jilabis*, *Motichoors*, *Darbeshes*, *Bundias*, *Moong laddus*, and a host of others of which *dal* forms the principal ingredient.] Indeed, one has only to go to a resident of Upper India, or better still, procure an invitation to dinner from him in order to disabuse one's self of the fiction that there is monotony in the *dal* diet. It is time that the Bengali ladies should improve the preparation of *dal* and introduce the very many dishes made of it in the daily dietary, and I confidently assert there will be no difficulty of any kind in taking *dal* in a larger quantity when presented in so many agreeable forms.

It should be remembered that *dal* contains about 50 per cent of starch, so that when taking it along with rice or *rooti*, the quantity of the latter could and should be advantageously reduced to corresponding extent.

The way in which we usually prepare rice for our

daily meals seems to be faulty, as thereby we lose some of the nutritive principles present in rice. In the first place, the rice grains are too finely cleaned; the outer coating of rice contains some of the proteid matter and nearly the whole of the salts, and, therefore, too much cleaning would remove those elements and make the grains poorer in nourishment. Then again, after we have boiled rice, we throw away the rice-water which takes away with it some of the nutritive principles from the grains and makes the prepared rice still poorer (about $\frac{1}{10}$) in proteids and salts. The proper way to prepare rice is to cook it slowly in steam or boil it over fire with just sufficient supply of water so as to cause the grains thoroughly soften and swell up without any excess of water being allowed to remain in the pot. This may be accomplished easily by a little practice. The rice is very conveniently and economically prepared in the " Ic-Mic Cooker " devised by the late Dr. Indu Madhab Mullick.

[*Khichery* is made by boiling rice and *dal* together to which *ghee* and spices are added. A more general and extended use of *khichery* by the rice-eating people of Bengal will, I strongly hold, be a great improvement in their dietary. If potatoes and some green vegetables are boiled with *khichery*, it forms almost a complete and very palatable food.] It is rich in proteid because it contains *dal*; it contains fat, because *ghee* is added to it; it contains enough of starch and it is rich in salts from the vegetables boiled with it. Those who cannot afford to use *ghee* may add oil to it or scrapings of the cocoanut kernel (or the milky juice pressed from the kernel) which will supply

the necessary quantity of fat, the fat in cocoanut kernel being in this respect an excellent substitute for *ghee*. *Khichery* is not a heavy food as it is popularly believed to be, unless it is prepared with too much *ghee* and spices. It is very much liked by children, and should, wherever possible, constitute one meal for them for the day.

[Rice in various other forms is used by the people of this country.] Some of these are *chira* (beaten rice), *moori* (parched and puffed rice), *khoi* (fried paddy cleared of the outer tough shell) and *chalbhaja* (fried rice). [*Moori*, *khoi* and fried *chira* are more nourishing than boiled rice and are more easily digestible, because the heat to which they are subjected during preparation dextrinises the starch of the rice grains and this helps digestion.] Apart from the principal meal of which rice forms the chief food, it is resorted to in one or other of its various forms by the poor people for extra meals in the morning and sometimes in the afternoon. If parched rice (*moori*) is taken along with parched or boiled grams or peas (*chhola* or *matar bhaja*) or *siddha* and cocoanut kernel (or sweetmeats prepared from cocoanut which are never costly), it would form an excellent all-round meal, and I may here point out that this, at one time, formed the only extra meal for all classes of the Bengalis. Such a combination is excellent not only on account of its containing proteids, fat and carbohydrates in good quantity but has the merit of being singularly free from all kinds of impurities (adulteration), and is so cheap that it could be largely availed of by poor people. I feel no hesitation in strongly recommending the

substitution of this healthy extra meal in place of the ordinary bazar sweetmeats or cheap *patties* and potato chops (generally made from stale meat and offals) which the boys of our hostels and messes are so fond of taking in the afternoon.

Wheat-flour should be substituted for rice for the evening meal as far as practicable. It contains nearly twice as much proteid as rice and is also richer in fat and salts. The whole-meal flour contains more proteid and salts than fine white flour and should be used in preference to the latter whenever available.* The whole-meal flour helps the action of bowels and is, therefore, suitable for people who suffer from constipation. For this reason, good *atta* is preferable to fine flour *(Maida)*. In preparing *rootis*, they should be rolled down quite thin and thoroughly baked on the oven, as otherwise many starch grains are likely to remain unbroken and these cannot be assimilated in that condition and will give rise to indigestion. The starch in English bread is more thoroughly baked ; good bread is, therefore, more easily digestible than *rooti*. Good brown bread is generally more nourishing than white bread. A substantial afternoon meal for our students may consist of bread and butter ; a bread for ½ *anna* and butter worth ½ *anna* supplemented by a few plantains will make an excellent tiffin and should supplant the ordinary tiffin of bazar sweetmeats purchased for the same value. Those who can afford to pay for one or two eggs (half boiled) or a couple of

* "The whitest loaf is the starchiest, the least rich in protein and, therefore, the least nourishing. 'Vitamines,' which are the nourishing constituents of whole-meal bread, do not exist in the white loaf."—*British Red Cross Society Hygiene and Sanitation Manual*.

good *sandesh*, could add these to the bread and butter tiffin with great advantage, as this combination would considerably make up for the deficiency in proteid and fat in their rice diet.

In hostels and messes, arrangements should be made to provide our boys with *rootis* instead of rice for the evening meal. As wheat-flour contains nearly twice as much proteid as that found in rice and as some *ghee* must be used for making the *rootis*, the deficiency of proteid and fat in the rice-diet would be somewhat made up in this way. The objection that I have heard frequently made to the supply of *rooti* in hostels and messes is that sufficient hands are not available to prepare them for a large number of boys. The employment of a few extra hands is all that seems to me to be necessary for the boys getting *rooti* in one of their meals. The financial difficulty, if there be any, could be obviated by each boarder bearing a small monthly cost in the shape of the salary of the extra servants, and to my mind, there would be ample compensation for the little extra charge on this head in the improvement effected in the daily diet by the substitution of the more nutritious wheat-flour for rice.

Chhana (fresh milk-curd) is an excellent proteid-food, richer both in proteid and fat than meat and fish. It is a comparatively cheap article, the average price throughout the year being eight annas per seer (2 lbs.). An *anna* worth of *chhana* weighs 4 ounces and will give 24 grammes of proteid and 21 grammes of fat, which is more than what one could get from any other food of the same weight. It may be taken with a little sugar or salt according to one's taste in the

afternoon. *Sandesh* is prepared from *chhana*, and good *sandesh* is undoubtedly the best form of sweetmeat, but it is costly. For an *anna*, you will get more food in *chhana* than in *sandesh* of the same value bought from the bazar.

For an *anna*, you can have a good quality of *mohanbhog* (*halwa*), a kind of Indian pudding prepared from *sooji*, *ghee* and sugar. One pice of *sooji*, one pice of sugar and half an anna of *ghee* will give you a plate-full of *mohanbhog* (6 to 7 ounces) which makes a substantial tiffin, *sooji* being richer in proteid than either *atta* or white flour. The addition of a small quantity of meal of parched gram (*chholar satoo*) will greatly increase its proteid value.

[Mangoes, jackfruits, pineapples, custard apples, bael, oranges and other kinds of fruits are sold cheap in their seasons and they should be taken in moderate quantity with one of the meals. Plantains are obtainable throughout the year and are rich in sugar (about 17%) and therefore nourishing. They are the cheapest of all fruits and should be eaten regularly. Nuts are very rich both in protied and fat, and should, wherever possible, be eaten in moderate quantity.]

[These are some of my suggestions for the improvement of the dietary of the Bengalis of ordinary means.] I have purposely refrained from making any reference to costly food, such as *loochies* and the many products of milk which find a prominent place on the tables of the rich people, as these are beyond the reach of the poor. They have their advantages when taken in moderation. Excess of such food, however, without

disorders of the bowels. The seeds may be collected at those places and a new business may be started in this way. They are quite good to eat, either boiled or baked, and form an excellent ingredient for a vegetable dish. They could be had cheap and they are very nourishing.

Cocoanut kernel was more largely used all over Bengal a generation ago than now. The fruits grow abundantly in the country and the kernel is very rich in fat. Cocoanut oil is very extensively used in Madras for culinary purposes as we use mustard oil in Bengal. In its appearance and composition, it resembles *ghee* more closely than any other vegetable oil. *Ghee* is differentiated from other edible fats and oils in that it contains the largest quantity of a special fat called Butyrate. The mutton-fat, tallow and lard contain only traces of butyrate, but cocoanut oil contains about $\frac{1}{4}$ the quantity found in *ghee*. It is, therefore, a good substitute for *ghee* in fresh condition when it emits no disagreeable smell. It is as cheap as mustard oil and could be got in almost any quantity. There is, however, hardly any necessity for substituting cocoanut for mustard oil in Bengal as long as we get the latter in plenty and in pure condition, but cocoanut kernel may be very advantageously used with our meals in various forms, either by being cooked with *dal* or other vegetables, or the kernel itself being taken raw, or by its being made up into various kinds of sweetmeats which are much less costly than the ordinary bazar sweetmeats and certainly more wholesome. "Narikel Sandesh" is six times as cheap as the "Sandesh" that is prepared from fresh milk-curd

(*chhana*) and although it is not so rich in proteid, it contains a large percentage of fat and is thus well able to supply this deficiency in our dietary at a small cost. [Cocoanut kernel should] therefore, [find a wider place in the dietary of the Bengalis.]

Among vegetables, potato is by far the best. Although it contains a small amount of proteid and fat, it is rich in starch and possesses certain important properties and gives a good amount of energy. It prevents scurvy (a kind of blood disease) and also helps to prevent fermentation in the intestines. It is also believed to have the power of dissolving uric acid and is, therefore, a valuable food in the constitutional disorder known as uric acid diathesis. About potato, Mr. James Long writes in his book on "Food and Fitness."—

"The potato always stands first among the vegetables for the garden, and there is practically no other variety upon which life can be maintained in health and strength. When acting a Commissioner for the 'Manchester Guardian' during the famine in the west of Ireland in 1897, I had abundant opportunities of observing how well those who obtain a sufficient supply of potatoes were able to work and maintain physical proficiency. It has been shown by prolonged experiments in Denmark by Dr. Hindhead, the Chief of the National Nutrition Department, that man can perform considerable labour on potatoes with the addition of a small quantity of margarine and continue to do so for many months in succession."

[Our young men are very fond of potatoes and it is only right that they should be so. From 8 to 10

ounces should be the average daily allowance of potato for a young man, and it should be taken baked, steamed, roasted or fried, in any one of which processes there is no loss of nutritive matter. Boiling causes loss of a good proportion of its proteids and salts. If boiled, it should never be done with the skin off.]

[The green vegetables which contain the largest amount of proteids are the green-peas and beans of various kinds. They should be largely used in the preparation of our vegetable dishes.] Dried kidney beans *(Barbati)* or gram or peas added to some of our vegetable dishes would considerably improve their proteid value. The sweet potato and unripe plantains are also nourishing vegetables containing about 21 and 17% of carbohydrates respectively. Beet root, *ole* and *mankachu* contain a fairly large proportion of carbohydrates and are, therefore, much superior to ordinary green vegetables.

I have considered the dietary of Bengalis of ordinary means in respect of its deficiency in proteid and fat, and I have suggested certain variations in it and recommended additions of some cheap articles of food, rich in proteid and fat, to make up the deficiency. In doing so, I have steadily kept in view the economic side of the problem, as the suggestions cannot otherwise have any practical value. It is no good recommending to a poor man meat, milk, eggs and other kinds of costly food which he cannot afford to buy. A poor Indian must have to depend mainly upon *dal* for obtaining the necessary amount of proteid. A wholesome dietary, I need hardly repeat, while

containing the requisite quantities of proteid and fat, must at the same time be such as to suit the pocket of every person of small income resorting to it.

This economic aspect of a national dietary is a question of vital importance to the poor of every nation and every country all over the world. I wish Europe had learnt to appreciate the value of *dal* as a good substitute for meat; the poor people there would fare much better socially and economically if meat is partially, if not wholly, replaced by pulses in their daily dietary. And much of the present difficulty* of procuring enough meat for the combatants and the serious trouble of regulating the daily meat-rations for the civil population would have disappeared, if England had, before this, recognised and adopted the general use of *dal* as a proteid-food of high value. And in support of my contention, I may be permitted to quote here the observations of Dr. Hutchinson, one of the greatest English authorities on Food and

* Some idea of the present difficulty in getting meat in European countries may be formed from the following statements taken from an English daily paper :—

"Bacon and eggs as the *piece de resistance* of a dinner in a good restaurant or club would have been considered unthinkable. It is by no means unthinkable now but extremely common. The nation could and would willingly submit to still further reduction of its meat-rations if the present scale interfered with the requirements of the boys at the front."

"So far as we know, horse-flesh has not hitherto entered into the diet of the inhabitants of the United Kingdom not even excluding the popular sausage. But according to a letter written by an English woman in Holland and published by the *Express* yesterday, the only meat obtainable in that Country is horse-flesh and it costs 5*s*.6*d* a pound."

Dietetics, regretting the practical exclusion of pulses from the dietary of the poor in England. He says :—

"As a cheap and efficient method of supplementing the deficiency of Nitrogen (i.e. proteid) in a purely vegetable diet, the use of pulses *(dal)* is strongly to be recommended, and it is a pity that they are not more largely taken advantage of by those to whom economy is of importance, for unquestionably pulses are amongst the cheapest of foods, and a given sum will yield more proteid if invested in them than in any other way."

I have stated that, besides helping the growth of the body and repairing the tissue-waste caused by work and exercise, there is another very important function of food, namely, the supply of heat and energy to the body. The greater the loss of heat from the body and the harder the work one has to do, the larger must be the quantity of food required for the supply of both. Now, all food-stuffs do not yield the same amount of heat and energy. The foods that produce the largest amount of heat and energy are fats and oils, and these are, therefore, largely consumed by people living in cold climates. Next to them are the carbohydrates (starch and sugar), the proteid-foods such as meat and fish, unless they contain much fat, occupying the lowest place in the scale. Fats generally

yield $2\frac{1}{2}$ times more heat and energy than starch or sugar and, therefore, this kind of food is the best for giving us strength and sustenance for our work. The popular idea that meat is an energy-giving food is erroneous.* It does give some energy no doubt, but in this respect, it is very inferior to fats and also to starch and sugar. It is pre-eminently a muscle-forming food; it assists the growth and repairs the waste of tissues caused by work.

[It has been ascertained b[illegible] [illegible]tual experiments how much heat could be p[illegible]oduced by one and the same quantity of different food-stuffs. This is expressed in calories, a calorie being t[illegible]ken as the unit of measurement of hea[illegible]] N[illegible]w w[illegible] know that there are various forms of energies, such as heat, electricity, chemical energy, mech[illegible]an[illegible]al [illegible]nergy etc., and that one form of energy [illegible] [illegible]il[illegible] converted and convertible into anothe[illegible] [illegible] c[illegible] be converted into mechanical [illegible]nergy (as in propelling engines) and mechanical energy in[illegible] h[illegible] [illegible]gain. In our body, the muscles and other tissues as well as the food circulating in the blood [illegible] being slowly burnt by the oxygen taken in by the lungs during the process of respiration, and heat is thereby produced. Part of this heat is used

* "At one time, it was believed that proteids were the chief sources of muscular energy, while the carbohydrates and fats acted as fuel and maintained the body-temperature. We now know this is a mistaken view." *Hutchinson.*

up for the maintenance of the body-temperature at the normal standard. The rest is converted into mechanical energy which enables us to perform work involving voluntary muscular exertions, such as walking, running, and doing the day's work, and it also helps the internal organs, such as the heart, the lungs etc. to perform their regular work which does not depend upon our volition.

It has been ascertained that for a moderate amount of exercise and work, a man requires 2800 to 3000 *calories* or *units of energy*, and this he must obtain from his daily diet. A dietary containing all the different nutritive constituents of food in necessary quantity and in proper proportions and which would supply a person with the required units of energy for both internal and external work, is, after all a matter of arithmetical calculation, Thus a man in good health and doing ordinary labour would require a daily diet which will furnish him with at least 1250 grains of muscle-forming element (proteid) and 2800 units of energy. I subjoin a table in which the amount of muscle-forming element (proteid) and units of energy obtainable from different food-stuffs purchased for an *anna* have been worked out. I hope it will be of use in making a selection of food-stuffs readily obtainable in the market for the construction of a wholesome dietary for people of ordinary means.

TABLE I.

Amount of muscle-forming element (proteid) and energy obtainable from an *anna* worth of various food-stuffs.

(Calcutta price.)

Food-stuffs.	Weight in ounces. (After deducting the waste)	Proteid in grains.	Units of energy.
Rice	14	364	1372
Flour	12	577·5	1200
Bread	8	280	560
Dal	12	1260	1104
Fish	2	150	80
Meat	2	175	150
Eggs	3	170	210
Milk	8	140	160
Dahi (sour milk)	9	182	163
Potato	16	140	560
Mustard oil	8	0	1776
Ghee	1·25	0	227
Butter	1·5	6·5	296
Chhana (fresh milk-curd)	4	391	304
Ground nut	8	840	914
Sugar	6	0	690

[Calculating the proteids, fats and carbohydrates in terms of Nitrogen and Carbon, we find that on an average, a Bengali adult in good health and doing a moderate amount of work, intellectual and physical, would require such a diet as would yield about 250 grains of Nitrogen (a little less than what is required by Europeans), 4500 grains of Carbon and from 2800 to 3000 units of energy in 24 hours. He would require more food when doing a greater amount of physical exercise.]

The following dietary would give him every one of the above things in the required amounts, if he is a pure vegetarian or if he cannot afford to provide for meat, fish or milk in his diet :—

TABLE II.

Food-stuffs.	Quantity in ounces.	Nitrogen in grains.	Carbon in grains	Energy units.	Cost. Rs.	A.	P.
Rice	8	28	1400	784	0	0	6
Flour	10	78	1660	1000	0	0	9
Dal (pulses)	4	64	624	345	0	0	7
Potato	6	9	270	150	0	0	5
Other vegetables	4	7	80	40	0	0	3
Mustard oil	1	0	219	138	0	0	3
Chhana (fresh milk-curd)	4	64	108	304	0	1	0
Goor (brown sugar)	2	0	178	115	0	0	3
Salts (spices etc.)	1	0	0	0	0	0	6
TOTAL	40	250	4539	2896	0	4	6

Such a dietary, on an average, would cost four annas and six pies only. The cost, however, may be further reduced by substituting *dal* for *chhana*, provided the power of digestion is good and a larger amount of exercise is taken.

I have said that the value of a food-stuff is estimated by the amount of the muscle-forming element (proteid) it contains and the units of energy it yields. Bearing this in mind, the table No. 1. shows that for the same money-value, viz. one *anna*, which is within the means of ordinary people, the largest amount of energy as well as of the muscle-forming element could be obtained from *dal*, and *dal* only. Meat and fish come very low in the scale in these respects. Further, it has been noted that as regards our staple food, i.e. rice, though it yields a large amount of energy, yet as it contains only a small amount of proteid, it should be taken combined with or supplemented by any of the other food-stuffs which are rich in proteid. Of these, *dal*, *chhana*, meat, eggs, fish and milk are generally used and from the table above referred to, it will be seen that for the *same money-value*. the largest amount of proteid is available from *dal*. Next comes the ground-nut and *chhana*. Meat, fish, eggs and milk, on account of their dearness, can never form the principal proteid-yielding food for ordinary people. *Chhana* is an article easily procurable, easily digestible, and for the same price, yields more than double the amount of proteid and energy than that obtainable from meat, and nearly 2½ times as much proteid and 4 times as much energy as would be yielded by fish. It is a pity that *chhana* is not more

largely used than at present to make up for the deficiency of proteid and fat in our ordinary diet. It should be freely used by our students for their afternoon meals.

For obtaining the necessary quantity of fat, the continued use of mustard oil which is the prevailing practice all over Bengal is all that is necessary. *Ghee* is and will be used by rich people, but mustard oil is quite a good substitute for *ghee* and much cheaper. A person would require daily at least 1 oz. of oil or *ghee* independently of the amount contained in the various kinds of food-stuffs forming his daily diet. Now, 1 oz. of *ghee* would cost about an *anna* but the same quantity of good mustard oil could be obtained for a pice only. And mustard oil has always taken the place of *ghee* in the diet of our poor people without any prejudice whatsoever.

In concluding, let me say that I have approached the consideration of this question with no prejudice against meat. But, if in working out a general dietary for those with whom this paper is primarily concerned and to whose religious feelings and social and economic conditions, one must give due consideration, I have shown any bias against any particular kind of food, I trust you will lay it, not at the door of any pre-conceived notion on my part but to the compelling logic of facts which have prevailed with me and which, I am sure, will tell its own tale to every one who will give to this subject the consideration it deserves. From all points of view, rice or flour, combined with *dal*, oil, salt and vegetables in their proper proportions (what we propularly call *Dal bhat or Dal rootee*) would form

the daily dietary of the majority of the Indian people and rightly they should. Only the people of Bengal should take a little less quantity of rice and a little larger quantity of *dal*. Such a diet has the sanction of age to recommend it and is one that agrees with the habits of the people and the natural conditions of the country, and on which even Science would pronounce its benediction. What more could the most exacting authority on food expect? Those, who can afford to do it, could add, as they often do, meat, fish, or milk or one or other of its various products to such a dietary which would make it not only agreeable but advantageous in many respects.

The importance of physical exercise as a valuable adjunct to food in the growth of the body and maintenance of health, should never be lost sight of, nor the dignity of labour under-rated. If you want to make your body supple and strong. if you would escape the odium that is too often levelled against the people of this country for the bulkiness of their frame and the indolence of their habits, if you want to keep your head above the surface in the keen struggle for existence that is going on around you, why then, you must have a sound mind in a sound body. And how else could you hope to attain to this except through the judicious intermingling of the right kind of food in right quantity and healthy work and exercise?

The larger the quantity of food you take, the more work and exercise you must perform to enable that food to be completely used up in your system, and the less work you do, the less must be the quantity of food for the day. This is a truism the importance of

which is seldom realised, not only by the people of this country but by those of other countries as well, and as a consequence of its breach, we see complaints arising from mal-nutrition and mal-assimilation of food such dyspepsia, diabetes, gout &c., from which a very large number of men suffer. [To those who suffer] from these disorders, [my advice is that they must learn to know how to regulate their diet according to their needs, and that what they require for regaining their health in not the doctor's prescription, but plenty of work and exercise with judicious regulation of diet.]

— o —

Amphimonadina
Mag.—800, Stained
by Leishman's Stain

Notes on Protozoa (Flagellate) fauna of the various sources of water supply in and about Calcutta.

By Rai Bahadur Dr. Gopal Chandra Chatterjee, B.A., M.B.

There are many difficulties in the study of protozoa fauna in this country. First and foremost of those is that there has not been published here a single systematic work on any of three main orders of free-living protozoa, viz., Sarcodina, Flagellata, and Ciliata. Second difficulty is due to the fact that though in European Countries numerous systematic works have been published on ciliates (both marine and fresh water)— works comparatively easy on account of ease of identification and of classification of the comparatively large sized ciliates offering several characters for classification,—the works on the other two branches of free-living protozoa which are the subject of my present paper, are most meagre. Systematic workers have been hampered in their work of identification and classification by the difficulty they experience in finding out specific and generic distinguishing points. The third difficulty, which is special to me, is the want of a reference library. Fully half the number of publications on this subject appears in journals which are not subscribed by any of the libraries to which I have access (the libraries of the Asiatic Society, of the Indian Museum and of the Medical College Biological and Bacteriological Laboratories.

From the publications available to me, I found that most of the workers studying fresh water flagellates and amœbæ, whether from public health point of view o pure biological point of view used some sort of culture media for multiplying their number and for keeping them alive for several days, so as to facilitate the study of them. Klebs who have described a large number of species of flagellates used boiled vegetable matter or section of fresh potato for this purpose. He has described.—

(1) A Mastigo-amœba.
(2) Four varieties of Dimorpha.
(3) A Phyllomonas.
(4) One variety of Spongiomonadina.
(5) A species he calls Streptomonas.
(6) Five varieties of Bodo.
(7) A species called Rynchomonas nasata.
(8) A Phyllomitus.
(9) A Amylophagus.
(10) One of Colponema.

He describes several species belonging to the genus Polymastigina. The following are some of the names of the species.—

(1) Tetramitus Brütschl.
(2) Do Sulcatus.
(3) Do Rostratus.
(4) Do Pyriformis.
(5) A species called Distomata.
(6) A species called Trigomonas.
(7) Hexamitus Dujardin.
(8) Do Inflatus.
(9) H. Pusellus.
(10) Do Fissus.

(11) H. Crassus.
(12) Do Fusiform.
(13) A species called Urophagus.
(14) 5 varieties of Treponoma.
(15) One species called Speronema.

Kleb's paper was published in 1892. It is however strange that very few of these species find their place in the systematic work on Protozoa by Dofflevn published in 1911.

Lauterborn studying the flagellates in the Rhine found—

A variety of Volvox.
A variety Biocœdæ.

Two species belonging to Chryso-monadina and a species belonging to chlamydomonadina.

Alexeiff describes some flagellates which he found in infusions—

Two varieties of Bodo.
A species called Phylomities.
A Cercomonas.
A Hexamitus fissus. (A species first described by Klebs.)
A species called Chilomonas Paramæcces.

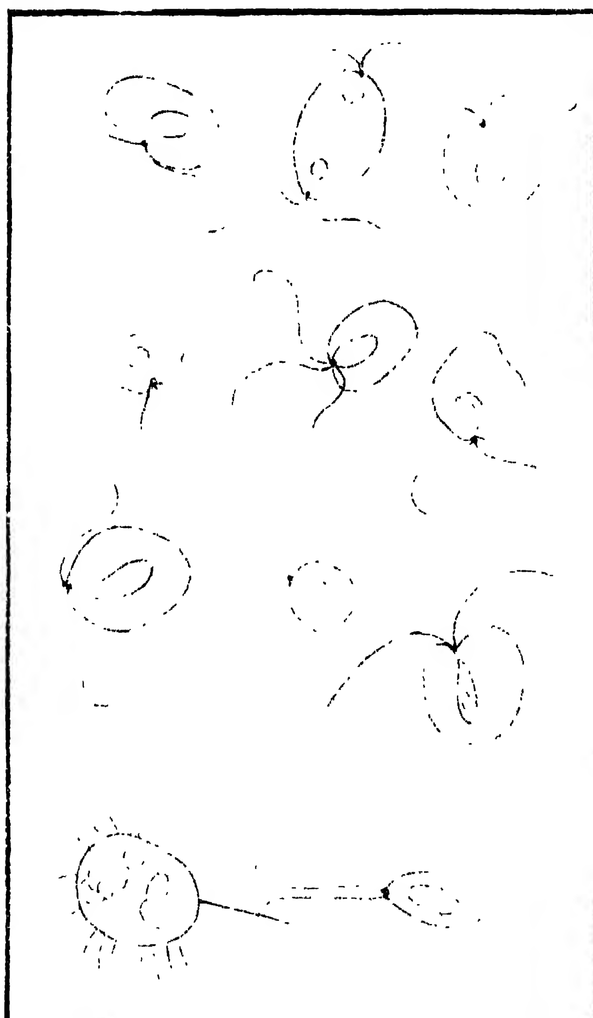
He describes the types of species found in different kinds of infusions.

Hartman and Chagas investigated free-living flagellates in tanks in Manguinhos (Brazil). They described a Cercomona Parva, an Amphimonadina, a Cryptomonadina, a Chloromonadina and an Euglenida.

The method I have followed in the study of the organisms I am going to describe, is as follows—

As it is a laborious and almost an impossible undertaking to find out a protozoa from a large quantity of water if examined by direct microscopical examination, I have had recourse to cultural methods for multiplying their number for separation of each species in pure state. I used at first Musgrave's medium. I later on found that Frosch's medium with a little modification served my purpose very well. I devised a plate culture method for separating the different varieties of the organisms. In this I used an ordinary Petri's dish. In the inside of the upper plate, I poured melted medium containing agar, which was allowed to spread in a thin layer*. In the lower lid, I placed a small quantity of sterile water, so that a moist chamber was formed. The whole thing after inoculation was kept at room temperature. I examined the culture without taking off the lid, under low power of a microscope with 12" eyepiece. On account of active movement the growing colonies can be easily found out in this way. A portion is taken out by a platinum loop and a smear is made and stained by Leishman's stain and is examined under oil-immersion. From this detailed structure

* At the time of completion of writing of my paper, I came across a review of a paper published in Archiv de Trop. Hygien by Noelter in which the writer describes a very same devise in cultivation and separation in pure state flagellates found in gut of insects. In this, he used perchloride of mercury solution instead of sterile water used by me for keeping the medium in moist condition. The culture media he uses are special for growing parasite flagellates,



Phyto flagellate.

can be easily studied. For more detailed study, I made an impression specimen with a cover glass and stained it by Iron-Hæmatoxylin.

As a rule, the first growth is a mixture of several varieties of flagellates. By 72 hours if there be any amœba in the water, they will outgrow all the other protozoa. By the end of the week, numerous spores of the amœbæ are found. This does not allow further study of the varieties of flagellates which might have grown in the plate. In case when no growth of amœba takes place, different species of flagellate grow separately. As each species has peculiarity in shape and movement, even when examined under low power, they can be fished out by a platinum loop and transferred to a test-tube containing Frosch's medium. When growth takes place in these media they can be examined at leisure and their characters can be determined In this way I separated and studied numerous different species of flagellates mostly belonging to Prowazekia class, some to Bodo, other to Amphimonads and a few to Phytoflagellate class. Though I have studied each species after being separated and cultivated in pure state by various methods morphologically (by making staining fixed specimen) and biologically, I found it difficult to describe their distinctive characters. Some can be differentiated by their size, or arrangement of the flagella or the nucleus. Most of them show movements which are peculiar to particular species. This peculiarity does not change even though they are kept in artifical culture for months.

The difficulty in describing the distinctive cha-

racters in case of the species of amœbæ found in water is much more pronounced, as they show very little differential characters. Two species of amœbæ growing in different plates can be easily made out as belonging to two different species when they are compared with each other, but in describing these the differentiative characters seem to be too minute to serve for specific characters.

Some of the species which show pronounced differential characters are described at the end of the paper. After studying the particular species, I tried next to find out the particular varieties in different samples of water; an attempt was made to find out any means by which a particular sample of water can be described as containing more or less number of protozoa than another sample. As all species of protozoa do not grow in plate culture, only a few types growing luxuriantly filling up all space in the plate, it is not possible to form any idea of the protozoa contents of any particular sample of water from the number of species growing in the plate. The only possible information we can derive regarding a particular sample is finding out the smallest quantity of the sample from which protozoa can be made to grow. Besides, the number of species found also indicate the peculiarity of the sample. For elucidation of all these problems I examined Calcutta filter water in all seasons of the year in varying quantities under different circumstances in order to form a standard and then I examined samples of water from different sources as river, tank, etc. From all these examinations I came to the conclusion that

in any time of the year protozoa grows in culture medium when more than 500 cc. of filter water is used. In samples of 10 cc. I failed very often to find any protozoa. The varieties which I found in Calcutta filtered water.

(1) A small amœbæ which is always present.

(2) Four or three varieties of Prowazekia.

These are very constant. No Phyto-flagellate or any other species have been found. In the river-water of the Hooghly, I found a rich culture of several varieties of species. Among these there were numerous varieties of ciliates including vorticella.

In tank-water, besides amœba of a particular big size, several varieties of Prowazekia unlike those found in fittered water and a large number of Phyto-flagellates were found. In one sample, the peculiar Prowazekia which I described in the Indian Journal of Research was found.

Description of some of the species.—

1. AMPHIMONADINA—

A species found in tank water (College square tank).—These grow in plate culture very luxuriantly, These are characterised by shooting character of their movement. They from a sort of colony in one part of the plate. I observed the colony for over two weeks without seeing any change in their movement. A stained film showed an oval bilateral symmetrical body, a single nuçlues, two prominent granules, bilaterally symmetrically placed, from which are seen originaling two flagella equal in size. The body of the protozoa is surrounded by a thick pellicle. The

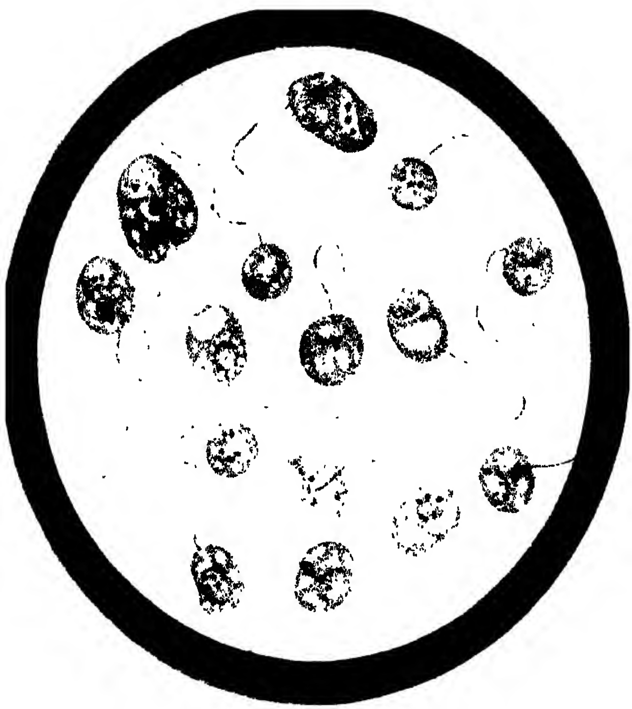
pabed basal granules take bright pink stain when stained by Giemsa and are very prominent.

2. A SPECIES OF PHYLOFLAGELLATE—

Found in tank water—These do not grow very luxuriantly in plate culture. When subcultured in Frosch's medium in a test tube and kept at room temperature, they give a peculiar greenish coloration to the upper surface of the culture medium which grows deeper as time goes on, till nearly half of the tube is coloured after a growth of 2 week's duration. When a moist preparation is examined under low power, these show a peculiar rolling movement which is very sluggish in comparison to movements of an Amphimonadina or a Prowazekia. Examined under the high power, the organisms are seen to possess near the posterior end a few green coloured granules. When these are fixed and stained by Giemsa, the following structures are seen—The body is rounded and is about 12 to 18 μ in diameter possesses a single central nucleus.

3. PROWAZEKIA—

Of the varieties of flagellates which grow easily in culture media and which are most constantly found in samples of water, are the species belonging to Prowazekia class. Besides, the number of species far exceeds that of any other variety of flagellates * This class is characterized by the possession of a nucleus, a blepparoplast and two flagella one of them serving as a trailing organ. The large number of different species belonging to this class offer so very few well marked distinguishing morphological characters, that for the



Bodo.

present I desist from describing all of them. Only the following three which offer easily detectable characters are described here : —

(1) *Prowazekia* N. Sp.—This was the subject of a paper in the Indian Journal of Research. It was found in a tank water. Subsequently I found the same species in the stool of a cholera patient. Both showed characters, absolutely identical. It is a very big organism, the most distinguishing character being its power to grow in any culture medium—ordinary agar, ordinary bouillon, Musgrave's medium, Frosh's medium—a character possessed, so far as I know, by no other Prowazekia. Stunton has found a Prowazekia of a similar nature as this, from urine of a patient. Macfie has described a Prowazekia growing in saline water, but it did not grow in ordinary media and also morphologically it possesses blepharoplast of a different shape. It is evindetly another species.

(2) *A Second Species of Prowazekia*—is much smaller organism. It is most frequent in Calcutta tap water. It is elongated, the length is about 3μ and breadth is from 1 to $1\frac{1}{2}\mu$, the blepharoplast is oval. It shows very active movement.

(3) *A third Variety of Prowazekia*—is a little bigger than the above; morphologically it cannot be differentiated from the above. Only it shows a peculiar jumping movement. This is not an accidental character, for I found this characteristic movement persisting in organisms kept in culture medium for over six months.

A peculiar flagellate found in foul water (septic

tank effluent), resembling the order Biocædæ in being enclosed by a transparent house, but differing from it in possessing four flagella. These organisms presented a most interesting peculiarity. The organism inside the house showed constant change of position sometimes occupying the middle of the house and, sometimes one corner. When stained it showed a vesicular nucleus at the anterior end, from near which four flagella were seen arising. This is a new .species altogether.

Besides these I found several varieties of amœbæ. As none of these, except one, shows any well-marked distinguishing characters, I do not intend to describe them. One of these showed well-marked pecularity in being small in size, and showed no movement, and no spore formation and lastly possessing the peculiar character of growing in bouillon at 37°. This has been described in the Proceedings of the Iudian Association for the Cultivation of Science, Vol. 3, No. 1. 1917,

Description of illustrations.

Plate No. I.—Amphimonadina stained by Leishman's stain. A central nucleus—a paired basal granules and two bilateral flagella are seen. Mag.—1000.

Plate No. II.—A phyto flagellate. Two paired flagella are seen—in the right hand corner a ciliata has been accidentally included in the plate.

Plate No. III.—Represents a Bodo—the smaller flagellum is not seen clearly.

Plate No. IV.—A pecies belonging probably to Biocœdæ.

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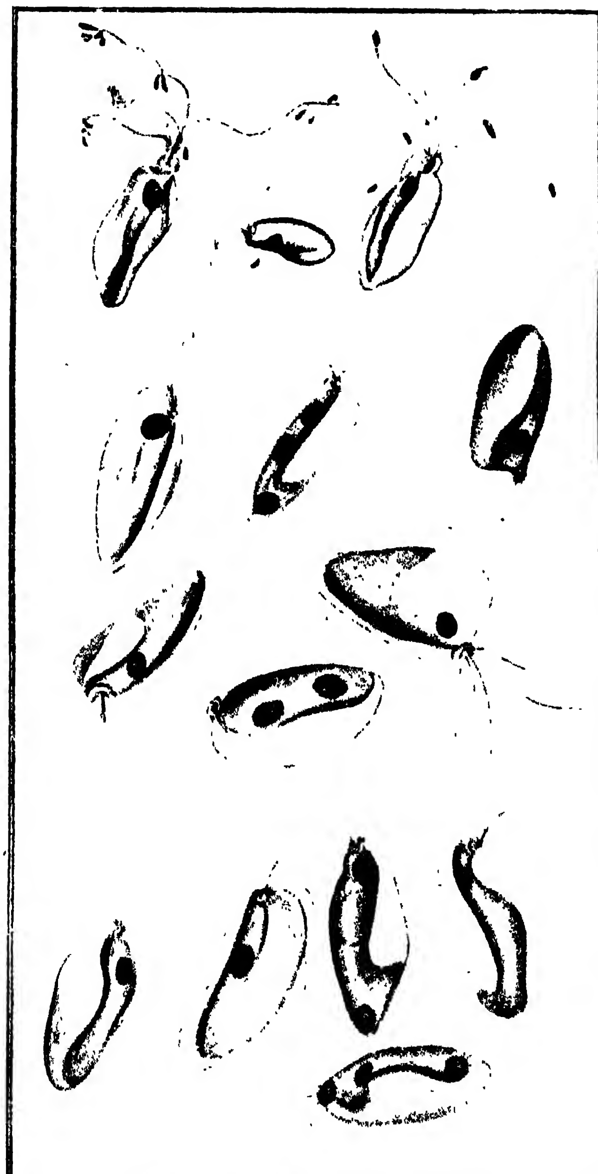

Fig. 1.

Fig. 2.

On the ova of a Distoma found in the skeletal muscles of Sacchobranchus fossilis.

By Gopal Chandra Chatterjee,
&
Bipin Behary Das.

§ 1. *Preliminary.*

In the year 1900 a peculiar eruption found in some of the fish brought in Calcutta markets gave rise to a popular view that they were in some way connected with the small pox epedemic prevailing at the time. We collected together some of the fish and examined them. A large number of fish of the species Sacchobranchus fossilis were found to be covered with a peculiar nodular eruption all over the body which proved to contain on examination the ova of an organism which could not be ascertained at the time. Afterwards it was noticed that the fish in many of the *Beel* of the Khulna District, Chagladah, Charaghatta, Ghatbhog, &c. were full of these eruptions from April to June. Recently we have been able to identify these as the ova of a distoma and also to prove that in its adult stage the distoma is a free moving worm, —a unique phenomenon in Distoma. We propose, therefore, to present to you this evening a preliminary note on the subject.

§ 2. *Distribution of the Disease.*

The parasitic ova infect only this variety of mud fish, *viz.* Sacchobranchus fossilis (vernacular name *Singhee*). The allied species, Clarius magur, has not been found to be infected in a single case. Besides

these the other varieties of the mudfish as well as the carps were found to be free from these parasites. The parasites were found to affect the fish in a particular water area. — nearly 75 per cent. of a lot obtained from one pond were found affected while the fish from another neighbouring pond were wholly free from the parasite. The fishermen also assert that the disease appears at certain season of the year. They state that at the beginning of the rains they (parasites) are plentiful. This was corroborated by our observation in the *Beels* of the Khulna District, where the infection was maximum from April to June.

§ 3. *Description of an infected Fish.*

An infected fish, if not extensively affected, does not look very unhealthy—a fish containing myriads of these ova will be found as active as the unaffected ones. The parts of the surface of the body of the fish where these nodular eruptions are found are the two portions on each side of dorsal fin and on the lateral surfaces near the caudal fin. A few are found in front of the gills underneath the mouth-cavity. On cutting open the muscles of the back on each side of the dorsal fin, the nodular bodies are found in innumerable numbers embedded in the muscles. On cutting open the thoracic and abdominal organs, a few are found on the surface of the heart, one or two on the stomach wall, the rest of the organs are found free as a rule.

The ova found in these nodular eruptions were seen in several stages of maturation. Some of these dissected out from the muscles and placed under microscope showed a capsulated organism showing vermicular movement. The very minute ones do not

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&
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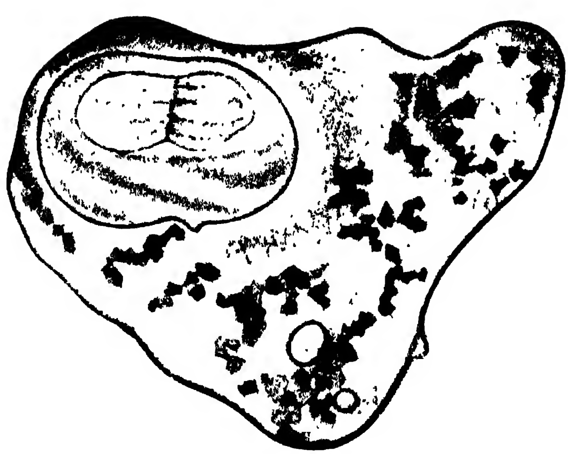
PLATE II.



show any movement. A nearly fully developed one taken out of its capsule and placed on a slide shows marked vermicular movement stretching out and contracting. These movements can also be easily observed with the naked eye.

One of these reaching nearly to the fully developed stage showed in the fresh state under the microscope two suckers, one situated at the anterior end (the mouth) being the oral one, the other situated a little behind it on the ventral surface—the ventral one. On each side of the body are seen two yellowish bands, all along the margin nearly up to the posterior end. These are the diverticula of the digestive canal. The middle portion of the body is found to be occupied by granular matter. When one of these organisms was killed in boiling spirit, then stained, cleared, and mounted, the organs described are seen a little more clearly but no other structure could be made out.

In one of the fish tubs of the fishermen containing these fish, we found two actively moving flat organisms being 4 times the size of the above described ones, *viz.*, those which were found in the nodules. These actively moving worms showed under low power of microscope bifid digestive canal along the margin like those found in the encapsulated larvæ and two suckers. Besides these, a clear oval transparent vacuole-like organ can be seen just behind the mouth on the dorsal surface which seems to be the sucking œsophageal pouch.

§ 4. *Movements of the free worms.*

As these are about one-third of an inch in length, the movements can be easily observed with the naked eye. When placed on a slide, it moves about very

quickly all over the slide, like earth-worm. It crawls underneath the slide, the anterior end is strenched out first, then the rest of the body follows. Placed inside a beaker containing water it can be seen moving about over the bottom of the beaker but not so actively as when not inside water. We kept one of these for 36 hours under this condition and found it at the expiration of this period as active as before.

It was killed then and stained and mounted. When one of these mounted specimens was examined under the microscope, the ventral sucker was seen clearly with an oval space surrounded by radiating bands. The ventral sucker was about 4 times the size of the oral one.

The digestive system could not be made out but in the posterior end of the body in the median line several ill defined convoluted tubules could be made out and similar ones are found in the anterior half of the body, in the similar situation. Probably they are the sexual organs.

It seems evident therefore that these freely moving big flat worms found in a free state in the fisherman's tub are nothing but the adult stage of the above capsulated ova found in the nodular eruptions of the fish. This view was confirmed by finding a worm creeping out actually under our eye from one of these tubercles found in the skin. When the free worm was examined, it resembled the adult free moving one in all its structure and appearance except that it was about half its size. Inspection of the surface of the skin of the affected fish shows the way these encapsulated larvæ become free. Some of the tubercles are found dis-

tinctly larger than the rest and look distinctly vascular. Some show the ulcer on the top of the tubercles surrounded by red and inflamed skin of the fish. Besides, a large number of linear ulcers can be seen studded all over the surface of the skin of the fish, which are about the size of the tubercles—the ulcers being emptied of larvae. It is evident, therefore, that these capsulated larvae first produce on the surface of the skin over the nodule, inflammation probably caused by secretion exuded by them and then an ulcer, after which they escape from the fish and become free. The big actively moving free ones are probably the adults of these as there are present several similar organs in these. Thus half the life cycle of the worm is clearly completed before our eye. The other half of the life cycle —the sexual union, liberation of ova getting entrance into the fish and lodgement of the ova in the skeletal muscles—requires to be worked out. It is clear, however, that the portion of the life cycle which we have observed is not complicated by the interposition of residence of the parasities in the body cavity of an intermediary host and also the production of asexual division, *viz.*, redii from Sporocyst, as happens in the case of other distoma. Besides another peculiarity is the occurrence of independent existence of the adult ones, which is unique among the distoma, for in the adult stage they are parasitic in the intestinal canal on some other situations of some vertebrata as a rule. Distoma have been found on several occasions as parasitic in fish, but not as parasitic in the tissues of the fish in the larval stage. A large number of the Distoma has been described by Löss who found the

adult ones as parasitic in the intestinal canal gall-bladder and urinary bladder of fish caught in the Gulf of Triest.

For the identification of the Distoma found by us a mounted specimen was sent to Mr. R. S. Leiper of the London school of the Tropical medicine to whom we are obliged for the following opinion. "The specimen appears to belong to Clinostominæ from what I can make out from the mounted slide." He suggested that the adult worm to be found parasite in some of the fish eating birds. Accordingly several ducks were fed with the infected fish. After three months the examination of all the internal organs of these ducks showed no trace of the parasite.

§ 5. *Description of the plates.*

Plate I. Fig. 1. A specimen of Sacchobranchus fossilis showing several white nodules near the dorsal fin and also near the ventral fin. These nodules are the cysts containing the embryo of the worm. *Fig. 2.* shows a dissected fish showing numerous nodules embedded in the muscles.

Plate II. Showing one of the cysts. In the left hand corner is situated the embryo taken out of its capsule. This show marked vermicular movement when alive.

Plate III. Fig. 1. represents a practically developed worm dissected out from a cyst. The succkers could be clearly made out. *Fig. 2.* shows a free living worm found in the water of the fishermen's tub. The two succkers could be clearly seen.

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&
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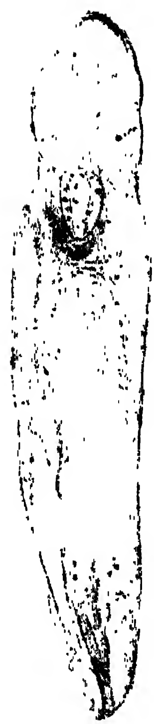
PLATE II.



Some Remarks on Physical Anthropology.

By—Dr. K. S. Ray, M.A., B.Sc., M.B.
Ch. B. *(Edin)*

§ *1. Introduction*

Considering the vast population of India and the diversity of races and customs affording ample facilities for anthropological investigations one would expect to find plenty of trained workers in the field. But unfortunately it is not so. The Universities in India do not as yet provide any opportunity for either research work or for teaching of Anthropology as a branch of natural science. The only place where a fairly complete set of anthropological instruments have been installed is the Laboratory of the Zoological Survey of India.

So far somatology has not received the same attention of the anthropologists as the purely anthropometric part. A large series of full size photograph of representatives of the very mixed population of Calcutta has recently been taken by Dr. Annandale, the Director of Zoological Survey of India. The following remarks are basad on the examination of those photographs which Dr. Annandale had very kindly lent me.

§ *2. Eye.*

Without entering into the detailed consideration of the eye as regards its colour &c., I shall show a few photographs showing how the Mongolian eye has been transmitted to children of Mongolian and non-Mongo

lian parents. Before doing that I shall explain briefly what the Mongolian eye is. It is characterised by its narrowness and obliquity of the rectus muscle of the eye and the anterior fold of skin which crosses the inner angle of the eye, obscuring the inner canthus. This anterior fold is associated with imperfect development of the nasal bones. It is not infrequent in European children disappearing as the nasal bones gain in prominence. The permanently smaller nasal bones of the yellow races in whom this fold is present, is possibly responsible for this condition. It appears that the Mongolian character is transmitted more markedly when the mother is Mongolian and to a less extent when the father is Mongolian but the mother is non-Mongolian.

§ *3*. *Trunk.*

The lateral walls of the trunk as a rule do not run vertically downward but converge towards the middle line somewhere below the rib margin, further down they again expand more or less over the region of the hip. This is best studied by examining a series of photographs of the trunk both front and back view. The examination of the series of photographs taken by Dr. Annandale brings out remarkable racial differences. The shape of the trunk has not been very much worked out from the anthropological point of view and there is no previous data with which to compare the following observations as far as I know.

The Chinese appear to have a more or less rectangular trunk i.e. the lateral walls of the trunk rnn vertically downwards without showing any convergence of the lateral walls towards the median line.


(1)
(5)
(8)

The lateral view or the profile of the trunk shows how the chest and abdomen are protruded or retracted in different races. In Bengalis and also to some extent among other Indians, it appears that the abdomen (more markedly in stout persons) do not form an uniform bulging. We find that that the umbellical and hypogastric regions tend to sag downwards and slightly outwords than the rest of the abdomen. This if confirmed by sufficient data would show that the Bengalis when compared with other races have a lower figure representing the distance of the umbellicus to the symphisis pubis when measured in the erect posture.

Whether this sagging down of the lower part of the anterior abdominal wall indicates a weakness in the tone of the muscles forming the anterior wall of the abdomen and a subsequent deposit of adipose tissue in that region due to the special diet is worth further investigation.

§ 4. *Appendix.*

The 1st. photograph shows diagramatically a non-mongolian eye with the inner canthus visible and the other a Mongolian eye with the inner canthus hidden by a fold of skin.

(2) *Eurasian*—Mother Eurasian, father English, the eyes show no epicanthic fold of skin to hide the inner canthi.

(3) Orissa sweeper same as above.

(4) Chinaman showing typical Mongolian eye with epicanthic fold.

(5) Mongolian eye in a German boy as an abnormality (taken from Rudolf Martin's Text book of Anthropology).

(6) *Burmese Eurasian*—Mother Burmese, father Eurasian, showing Mongolian eye.

(7) *Bhutia Eurasian.*—Mother Eurasian, father Bhutia: shows Mongolian eye on one side only.

(8) *Chinase Eurasian.*—Mother Eurasian, father Chinaman, not showing the Mongolian eye.

Trunk.

(9) *English*—shows how the lateral walls of the trunk converge towards the middle line below the margin of the ribs, it then expands at the hip.

(10 *Armenian*—same as the previous slide.

(11) *Negro*—showing the convergence of the lateral walls at the sub-costal margin but not showing the expansion at the hip so well.

(12) *Javanese*—showing slight convergence.

(13) *Chinese*—showing practically no convergence.

(a) front view.

(b) back view.

Lateral views of trunk.

(14) Bengali Bania.

(15) Negro.

(16) Bengali—Brahmin.

(17) Bengali—Baidya.

(18) Bengali—Brahmin.

APPENDIX.

METEOROLOGICAL OBSERVATIONS

Taken in the Laboratory

OF

THE INDIAN ASSOCIATION FOR THE CULTIVATION OF SCIENCE.

1917.

Meteorological Observations taken at 8 A.M.

JANUARY, 1917.

Date.	Barometer. (corrected)	Wind. Direction.	Wind. Velocity per hour in miles.	Temperature. Maximum.	Temperature. Minimum.	Humidity.	Cloud Proportion.	Rainfall in inches.
1	30·053	Calm	1·5	73·5	54·0	63		
2	·069	N W	1·9	74·0	54·0	64		
3	·055	N	1·8	73·5	54·0	67		
4	·065	N	2·2	74·0	55·0	53		
5	·089	N	1·9	74·0	54·5	61		
6	·116	Calm	1·9	74·0	53·0	72		
7	·096	N W	1·9	74·0	55·0	70		
8	·120	N W	1·9	74·5	55·0	67		
9	·170	N	2·8	74·0	55·0	67		
10	·169	N W	2·5	74·5	57·0	70		
11	·163	W	2·0	75·0	58·0	71		
12	·100	N W	1·4	77·0	57·5	76		
13	·068	Calm	1·2	77·0	58·0	82		
14	·109	Calm	0·8	78·5	59·0	76		
15	·068	Calm	1·2	78·0	60·0	72	7	Nil
16	·041	N	1·5	77·5	60·5	72		
17	·038	Calm	1·3	79·0	60·0	89	1	
18	·034	Calm	0·5	82·5	62·0	78		
19	·050	N W	2·2	80·5	59·5	52		
20	29·990	Calm	1·1	79·0	59·5	62		
21	30·003	Calm	0·8	80·0	58·5	67		
22	29·989	Calm	0·6	79·5	59·5	94		
23	·932	S	1·3	80·0	60·0	97		
24	·980	E	1·8	86·5	66·5	97		
25	·957	N	1·0	84·5	64·5	43	1	
26	·981	Calm	1·0	83·5	63·0	73		
27	·984	Calm	1·0	85·0	64·0	97	10	
28	·968	Calm	1·6	84·5	65·5	95		
29	30·036	N	2·9	85·0	66·0	61	8	
30	·058	N	2·4	83·5	63·5	76		
31	·089	N W	2·3	83·0	60·0	68		
Mean	30·053	42N23°W	1·3	78·7	59·1	73	1	TOTAL *Nil*

Meteorological Observations taken at 8 A.M.

FEBRUARY, 1917.

Date.	Barometer. (corrected)	Wind. Direction.	Wind. Velocity per hour in miles.	Temperature. Maximum.	Temperature. Minimum.	Humidity.	Cloud Proportion.	Rainfall in inches.
1	29·995	Calm	2·2	82·0	64·5	53	9	
2	·913	Calm	1 5	81·0	62·5	81		
3	·994	E N E	1·2	82·0	65·0	65	[illegible]	
4	30·010	Calm	1·1	80·5	65·0	84	10	0·17
5	29 980	Calm	2·3	76·0	60·0	85	10	0·55
6	30·032	N	1·5	73·5	58 0	82		
7	·109	Calm	2·0	74·0	59·0	80	8	
8	·148	N W	0·9	73 5	58·0	76		
9	·128	N	2·0	76·5	58·0	66		
10	·013	Calm	1·6	78·5	60·0	62		
11	29 846	N N W	2·5	81·5	63·0	61	7	
12	30·008	Calm	1·5	82 0	69·0	95	8	
13	·068	N W	1·6	81·0	64·5	80	1	
14	·020	N	1·8	80·0	62·2	77		
15	·036	Calm	1·5	81 0	64·5	84		
16	·048	Calm	1·8	82·0	65 0	89		
17	29·913	N W	2·8	82·0	66·5	82		
18	·834	Calm	2·5.	83·5	67·5	92		
19	·762	S	2·2	84·0	68·5	86	7	
20	·795	S	1·7	85·0	68·0	95	8	
21	·820	S	2·2	85·0	69·0	86	4	
22	·840	S	3·7	85·5	73·5	84		
23	·850	S	4·8	87·5	73·5	77		
24	·804	S S W	1·4	86·0	73·0	72	10	0·08
25	·807	Calm	4·6	83·5	71·0	88	6	0·21
26	·810	N	1·4	85·5	69·0	76	6	0·17
27	·864	N E	1·3	83·5	65·5	42		
28	·914	N W	1·3	84·0	62·0	50		
Mean	29·941	14N34°W	2·0	81·4	65·2	77	4	TOTAL 1·18

Meteorological Observations taken at 8 A.M.

MARCH, 1917.

Date.	Barometer. (corrected)	Wind. Direction.	Wind. Velocity per hour in miles.	Temperature. Maximum.	Temperature. Minimum.	Humidity.	Cloud Proportion.	Rainfall in inches.
1	29·890	S S E	3·7	84·5	64·5	58		
2	·851	Calm	2·2	85·5	65·0	61		
3	·782	S	2·7	86·0	69·0	74		
4	·756	N	3·7	84·5	70·0	62	8	
5	·836	N N E	1·1	85·5	71·0	81	6	
6	·843	N E	2·5	84·5	70·0	80	7	
7	·866	E	2·8	83·0	66·0	85		0 76
8	·950	Calm	1·7	83·5	67·0	92		
9	·961	W N W	1·7	84·0	64·0	67		
10	·966	Calm	1·5	84·5	66·5	60		
11	·853	W	1·2	84·5	68·5	81		
12	·832	S	2·0	84·0	71·5	77	6	
13	·832	N	2·5	84·5	73·0	83	2	
14	·888	Calm	1·8	86·0	72·5	84		
15	·897	S S W	1·0	86·5	70·5	67		
16	·852	S	2·0	86·5	70 0	88		
17	·779	S	3·5	85·0	72·0	84		
18	·813	S	5·3	86·5	77·0	76	3	
19	·863	S	4·2	86·0	76·5	82	4	
20	·857	S S W	3·0	85·0	76·0	82	5	
21	·846	Calm	2·3	86·5	74·0	80		
22	30·042	Calm	2·8	86·0	69·5	82	10	0 07
23	29·991	Calm	0·8	76·0	68·0	78		0·16
24	·924	W	1·4	84·0	72·0	77	8	
25	·880	S S W	1·8	85·5	75·0	82		
26	·924	Calm	1·8	85·0	76·0	74		
27	·898	S S W	1·9	85·5	76·0	80	3	
28	·932	S	1·8	92 0	74·5	89	2	
29	30·010	W S W	1·1	90·0	75·5	44		
30	29·957	W	1·7	88·5	76·0	47		
31	·813	S S W	3·2	88·0	76·0	40	2	
Mean	29·883	9S30°W	2·3	85·4	71·4	72	2	TOTAL 0·99

Meteorological Observations taken at 8 A.M.

APRIL, 1917.

Date.	Barometer. (corrected)	Wind. Direction.	Wind. Velocity per hour in miles.	Temperature. Maximum.	Temperature. Minimum.	Humidity.	Cloud Proportion.	Rainfall in inches.
1	29·805	N N W	3·1	87·5	76·5	58	3	
2	·797	W	3·2	87·5	79·0	81	6	
3	·813	E	2·5	89·0	77·5	83		0 01
4	·843	S E	2·1	86·5	76·0	78	5	
5	·769	S S E	3·7	87·5	79·0	79	4	
6	·755	S S W	5·0	87·5	79·0	75	2	
7	·765	S	2·8	86·0	78·2	77	3	
8	·736	S	2·3	87·5	78·0	82	10	
9	·716	S S W	2·7	80·0	74·0	98		
10	·768	S	3·0	95·5	71·5	81		1·28
11	·763	S	3·2	83·0	75·0	71		0·04
12	·694	N	2·7	88·0	78·5	73	4	
13	·659	Calm	2·2	83·5	77·5	71		0·27
14	·705	Calm	1·7	89·5	80·0	83	6	
15	·729	S S W	2·8	88·0	80·0	75	3	
16	·709	S	2·3	88·5	73·0	87	7	0·11
17	·705	S	2·1	88·0	79·0	87	4	
18	·679	S	2·9	88·0	78·5	81	3	
19	·713	S S W	5·3	96·0	81·0	74		
20	·679	S	6·1	96·0	82·0	68	5	
21	·719	E	7·2	91·0	80·5	76		
22	·759	S	2·9	97·0	77·0	78		
23	·825	S	3·7	97·0	69·5	70		0·11
24	·869	W	2·6	?	74·0	61		
25	·836	W S W	2·7	?	75·0	57		
26	·811	S S E	2·5	?	77·0	56		
27	·744	S	2·1	106·5	77·5	49		
28	·760	S	3·5	108·0	80·0	42		
29	·747	S S E	4·0	106·0	80·0	66		
30	·776	S S W	3·4	108·0	78·0	98		
Mean	29·755	63S3°W	3·2	91·7	77·4	74	2	TOTAL 1·82

Meteorological Observations taken at 8 A. M.

MAY, 1917.

Date.	Barometer. (corrected)	Wind. Direction.	Wind. Velocity per hour in miles.	Temperature. Maximum.	Temperature. Minimum.	Humidity.	Cloud Proportion.	Rainfall in inches.
1	29·752	S	4·1	100·5	80·0	53	5	
2	·817	S	3·1	100·0	81·0	72	6	
3	·712	E	3·0	92·0	77·5	82	10	0 07
4	·693	S	8·5	78·0	73·0	93	9	1·00
5	·798	S	2·7	89·0	73·0	85	7	
6	·788	S S E	2·0	95·0	75·0	67	7	
7	·776	S	1·9	94·0	75·0	63		
8	·696	Calm	2·4	96·0	76·5	61	8	
9	·747	S E	3·5	93·5	73·0	67	2	
10	·766	Calm	2·7	93·0	71·0	82	8	1·92
11	·702	Calm	1·7	94·0	72·0	86	9	1·78
12	·666	S	1·7	93·5	76·0	75	3	
13	·712	Calm	1·0	93·0	74·0	78	4	0·28
14	·746	N	1·5	93·0	76·0	77	3	
15	.764	S	2·4	96·0	80·0	76		
16	·826	Calm	2·4	99·0	73·0	83	2	1·48
17	·817	S S E	2·7	97·0	79·0	70		
18	·831	S S W	2·9	100·0	80·5	72		
19	·863	S S W	2·7	102·5	81·0	62		
20	·836	S W	3·2	103·0	81·0	65		
21	·792	S	2·6	103·0	81·0	76	2	
22	·758	W N W	3·4	100·0	72 0	[illegible]		0·30
23	·751	S	2·4	100 0	81·5	69	3	
24	·744	S	3·4	99·5	80·0	71		
25	·679	S	2·4	101 0	78·5	76		0·46
26	.675	S	1·9	100·0	79·0	70		0·06
27	·649	S E	2·7	102·5	77·0	70	8	0·14
28	·712	N	2·6	95·5	77·0	74	6	0·05
29	·713	Calm	2 0	100·0	76·0	63	4	0·32
30	·719	W	1·6	100·0	81·0	72	2	0·02
31	·691	S S W	1·8	100·0	81·0	69	2	
Mean	29·748	52S4°W	2·7	96·9	77·1	71	4	TOTAL 7·88

Meteorological Observations taken at 8 A.M.

JUNE, 1917.

Date.	Barometer. (corrected)	Wind. Direction.	Wind. Velocity per hour in miles.	Temperature. Maximum.	Temperature. Minimum.	Humidity.	Cloud Proportion.	Rainfall in inches.
1	29·644	S	3·0	100·0	82·5	68	3	
2	·620	S S E	3·3	99·5	80·0	74	2	
3	·585	E	3·0	97·0	77·5	77	6	0·19
4	·600	S S E	2·8	96·0	75·5	76	4	0·71
5	·685	E	3·4	96·0	82·0	76	3	
6	·730	S E	3·4	97·0	82·5	76	6	0 01
7	·723	S	1·6	92·0	81·5	78	4	0·14
8	·692	E	2·2	91·5	80·5	82	5	0·25
9	·610	S	1·7	92·5	78·0	77	5	1·77
10	·560	E	2·1	90·0	80·0	91	8	
11	·517	N E	2·0	88·0	79 5	87	9	
12	·467	Calm	2·1	95·0	78 0	89	10	0·37
13	·374	S W	2·1	91·0	76·0	95	10	1·13
14	·390	S S E	2·2	83·0	76·5	95	10	0·94
15	·622	S E	2·5	84·0	77·5	91	8	0·25
16	·703	S	2·2	89·0	80·5	85	5	
17	·587	S S W	2·3	95·0	82·0	80	10	
18	·557	N	2·4	96·0	78·0	89	10	0 80
19	·456	Calm	1·0	91·0	79·0	85	6	0·14
20	·439	Calm	1·1	94·0	79·5	79	6	0·40
21	·466	S	2·3	91·5	78·0	82	10	0·26
22	·514	S S W	3·9	86·0	75·5	77	10	1·25
23	·518	E	3·0	90·5	75·5	89	8	0·67
24	·547	S S W	2·8	94·5	81·0	84	4	
25	·581	Calm	1·8	96·5	83·0	81	9	
26	·480	E N E	1·1	93·0	77·5	91	7	1·13
27	·484	N	1·6	91·0	79·5	85	8	1·57
28	·466	E	4·5	91·5	80·0	87	10	0·06
29	·606	S E	4·0	88·5	79·0	91	6	0·57
30	·596	S	4·2	88·0	80 0	83	4	0·10
Mean	29·561	47S42°E	2·5	92·3	79·2	83	7	TOTAL 12·71

Meteorological Observations taken at 8 A.M.

JULY, 1917.

Date.	Barometer. (corrected)	Wind. Direction.	Wind. Velocity per hour in miles.	Temperature. Maximum.	Temperature. Minimum.	Humidity.	Cloud Proportion.	Rainfall in inches.
1	29·544	S	3·4	91·5	82·0	79	6	
2	·564	S S E	2·4	92·5	78·0	91	10	1·27
3	·625	Calm	2·6	88·0	76·0	95	10	1·46
4	·702	S	2·9	81·5	77·0	89	10	0·86
5	·682	Calm	3·1	89·0	76·5	83	9	0·23
6	·600	Calm	2·5	90·5	76·5	93	10	0·59
7	·529	N W	1·5	86·0	78·5	81	8	0·14
8	·500	Calm	1·4	90·5	83·5	78	6	
9	·458	W N W	0·9	93·0	81·0	83	6	0·41
10	·438	Calm	0·9	91·0	81·0	87	4	0·67
11	·506	S	1·1	90·0	80·0	87	6	0·25
12	·548	S E	1·3	90·0	81·5	85	4	0·17
13	·594	S E	2·1	93·0	80·0	85	4	0·14
14	·552	E	2·7	92·5	81·0	83	7	0·04
15	·498	E S E	2·1	91·0	81·0	87	10	
16	·470	E	1·5	90·0	80·0	87	10	0·12
17	·484	E	2·5	92·0	81·0	83	6	
18	·476	E S E	2·3	90·0	80·5	83	8	0·17
19	·480	E	1·7	91·0	81·0	83	8	0·14
20	·472	E	2·1	94·5	81·5	85	10	0·18
21	·481	E N E	3·0	93·0	81·5	81	5	0·01
22	·475	E	2·2	92·5	81·0	83	7	0·30
23	·482	E	2·6	92·0	80·0	85	6	0·15
24	·502	S	3·2	90·0	81·0	87	4	2·17
25	·483	S	3·2	93·0	82·0	87	10	
26	·472	W	2·6	89·0	79·0	89	10	0·90
27	·479	Calm	3·4	83·5	78·5	85	9	
28	·495	Calm	3·2	85·0	79·5	96	5	0·28
29	·474	S E	2·3	88·5	80·0	87	8	
30	·448	N W	1·8	95·5	79·5	91	10	0·48
31	·459	S	2·7	88·5	79·0	91	10	0·78
Mean	29·515	36S52°E	2·0	90·3	80·0	86	8	TOTAL 11·91

Meteorological Observations taken at 8 A.M.

AUGUST, 1917.

Date.	Barometer. (corrected)	Wind. Direction.	Wind. Velocity per hour in miles.	Temperature. Maximum.	Temperature. Minimum.	Humidity.	Cloud Proportion.	Rainfall in inches.
1	29·509	S S W	4·4	87·0	79·5	81	6	0·13
2	·537	S	3·3	87·5	79·0	83	10	0·36
3	·586	Calm	3·3	90·0	80·5	89	5	0·04
4	·527	S	3·0	93·0	82·0	87	10	
5	·602	Calm	1·5	92·5	79·0	83	7	0·15
6	·552	S E	1·6	92·5	78·0	87	6	0·97
7	·470	N E	2·1	92·0	81·5	85	9	
8	·490	S E	2·8	90·5	79·5	89	10	0·46
9	·836	S	3·4	89·0	77·5	95	10	1·32
10	.652	S W	2·2	81·0	76·5	93	10	4·35
11	·653	Calm	1·5	85·0	78·0	93	10	0·02
12	·653	Calm	1·8	87·0	76·5	91	8	0·65
13	·725	E	2·8	86·5	76·0	93	10	0·46
14	·771	Calm	2·1	86·0	79·0	93	7	0·06
15	·712	S	2·1	89·0	80·0	83	4	
16	·679	S S W	3·1	92·5	82·0	83	7	
17	·645	Calm	1·1	91·0	81·0	81	10	0·03
18	·668	S S W	1·2	87·0	78·5	89	10	0·13
19	·668	S W	1·2	89·0	78·5	87	3	0·01
20	·660	Calm	2·9	93·5	79·5	79	4	0·13
21	·645	Calm	1·2	93·5	81·0	85	10	0·13
22	·655	E	1·1	93·0	82·0	80	3	0·07
23	·653	S W	1·1	94·0	82·5	91	10	
24	·728	S E	3·6	96·5	80·5	85	8	0·06
25	·735	S S E	2·8	88·0	78·5	95	10	0·35
26	·691	S E	3·3	89·0	79·5	81	6	0·04
27	·628	S E	2·5	86·5	79·5	89	7	0·55
28	·722	S E	2·7	90·0	80·0	85	8	0·31
29	·781	S S E	2·8	93·0	80·5	86	6	0·29
30	·706	S S E	2·9	89·5	80·0	89	8	0·04
31	·608	S	2·4	90·0	80·0	83	4	0·03
Mean	29·650	55S21°E	2·4	89·8	79·5	87	8	TOTAL 11·14

Meteorological Observations taken at 8 A.M.

SEPTEMBER, 1917.

Date.	Barometer. (corrected)	Wind. Direction.	Wind. Velocity per hour in miles.	Temperature. Maximum.	Temperature. Minimum.	Humidity.	Cloud Proportion.	Rainfall in inches.
1	29·626	E N E	2·7	94·0	82·0	81	5	
2	·652	E	2·9	92·0	80·0	89	10	0·03
3	·605	S E	2·2	93·5	80·5	85	5	0·15
4	·522	E N E	3·2	94·0	80·5	83	4	0·02
5	·568	E	2·9	95·5	81·0	81	6	0·02
6	·605	S E	1·8	97·0	83·5	85	10	
7	·638	S S E	3·2	93·0	80·5	87	8	0·12
8	·623	S E	3·7	90·0	81·0	81	4	
9	·694	N	3·4	91·5	77·5	91	10	0·92
10	·726	S S E	2·0	92·0	79·5	83	5	0·08
11	·738	Calm	1·6	97·0	82·0	79	3	0·40
12	·743	Calm	1·2	89·5	76·0	95	10	0·75
13	·690	Calm	0·9	87·0	76·0	91	10	0·61
14	·692	E	0·9	85·5	75·0	87	6	1·33
15	·681	Calm	1·9	88·5	77·0	95	10	0·44
16	·709	E	2·0	82·0	77·0	89	10	0·07
17	·714	Calm	2·1	86·5	77·0	93	9	0·95
18	·702	S S E	2·7	87·0	76·0	91	10	
19	·769	E	1·4	86·0	77·5	87	5	0·05
20	·851	S	1·6	87·0	77·5	91	8	0·72
21	·849	Calm	1·2	89·0	78·5	87	9	0·24
22	·860	S E	1·8	89·0	79·5	87	5	
23	·862	Calm	0·8	88·0	78·0	91	3	0·69
24	·818	E N E	1·1	92·0	80·0	87	7	0·03
25	·778	Calm	1·7	94·0	78·0	77	3	
26	·786	S S E	1·5	91·0	79·0	85	5	0·31
27	·828	S	1·9	91·0	80·0	79	7	
28	·775	Calm	1·7	94·5	80·5	83	2	
29	·728	Calm	1·4	95·0	81·0	72	2	0·05
30	·682	N E	1·2	94·0	79·5	68	4	
Mean	29·650	43S67°E	2·0	90·9	79·1	85	7	TOTAL 7·98

Meteorological Observations taken at 8 A.M.

OCTOBER, 1917.

Date.	Barometer. (corrected)	Wind. Direction	Wind. Velocity per hour in miles.	Temperature. Maximum.	Temperature. Minimum.	Humidity.	Cloud Proportion.	Rainfall in inches.
1	29·644	E	2·2	93·5	79·5	89	10	0·13
2	·652	E	3·3	84·5	78·0	93	4	0·61
3	·613	N E	1·9	87·0	79·0	89	7	0·56
4	·603	S E	3·5	88·0	79·5	91	10	0·32
5	·602	E S E	3·2	88·0	76·0	95	10	0·94
6	·574	S S E	2·8	79·0	76·0	95	10	2·63
7	·615	S	5·1	82·0	76·0	91	10	1·85
8	·698	W N W	5·4	88·0	75·0	82	10	1·25
9	·783	Calm	1·9	82·0	74·5	88	10	
10	·815	Calm	1·3	90·0	76·0	89		
11	·848	N N E	0·6	87·5	77·0	76		0·27
12	·878	S E	0·9	91·5	78·0	83		
13	·942	E	1·3	91·5	78·0	75	2	
14	·924	Calm	1·4	93·5	78·5	77	1	
15	·880	Calm	0·9	94·5	79·0	72	1	
16	·881	Calm	1·4	95·0	80·0	72	2	
17	·829	N	1·6	95·0	79·0	75		
18	·834	E S E	0·9	89·5	79·0	79	4	
19	·868	N	0·9	91·5	78·0	75	2	
20	·944	N N E	1·3	93·0	79·0	68		
21	·880	E	1·2	93·0	79·0	71		
22	·884	E	1·0	94·0	79·5	67		
23	·885	E	1·2	94·5	78·5	65		
24	·896	E	1·4	95·0	78·0	65		
25	·844	E	1·0	95·0	77·0	69		
26	·836	N	1·8	95·0	78·0	67		
27	·815	N	1·3	95·5	78·0	79	3	
28	·794	N	2·0	95·0	78·0	79	2	
29	·762	E	2·7	93·0	78·5	91	10	0·62
30	·599	E S E	3·2	92·0	76·5	100	10	2·45
31	·571	S	3·4	79·0	75·0	95	10	2·20
Mean	29·780	45N78°E	2·0	90·5	77·8	81	4	TOTAL 13·83

Meteorological Observations taken at 8 A.M.

NOVEMBER, 1917.

Date.	Barometer. (corrected)	Wind. Direction	Wind. Velocity per hour in miles.	Temperature. Maximum.	Temperature. Minimum	Humidity	Cloud Proportion.	Rainfall in inches.
1	29 911	N	1 4	81 0	74 0	69	2	0·02
2	871	N	1 2	82 5	73 5	65		
3	·963	N	2 4	86 0	76 0	60		
4	·968	N	1 5	85 5	77·0	62		
5	990	N	3 0	85 0	69·0	72		
6	990	N W	2·9	84 0	69 0	74	4	
7	·962	N N W	3 2	84 0	69 5	74	6	
8	938	N	3 3	85 0	71 0	84	3	
9	885	N	2 2	86 0	71 5	86	1	
10	·886	N N W	2 1	87·5	72·0	82	5	
11	862	N N W	2 8	87·5	73 0	77	6	
12	·850	N N E	2 6	88 0	73 5	73	2	
13	880	N N E	2 3	90·0	75·0	86	10	
14	854	N N E	1 5	85 5	75 0	98	10	0 27
15	886	N	1 2	86 5	75·0	87	3	
16	879	N	2 0	86 0	75 0	70	2	
17	·913	N	3 1	86 0	69 0	64		
18	·927	N	1 7	84 5	70 0	58	10	
19	981	E	2 0	84 5	66·0	66		
20	994	N N W	1 6	81 0	62 0	64		
21	30 017	N N W	1 5	80 0	64 5	70		
22	·024	N W	1 7	81 0	66 0	73	3	
23	29 975	N W	2 1	82 0	65 5	82		
24	958	N N W	1·2	83 0	67·0	78	2	
25	·928	N N W	0 9	87 0	68·5	78	1	
26	990	N N E	1 2	85 5	69 5	66	7	
27	983	N	1·2	80·0	66 5	75		
28	30 020	N	2 4	83 0	67 0	75		
29	068	N	2 4	83·0	66 0	73	4	
30	·080	N N W	3 6	82 5	65 0	72		
Mean	29 948	77N18°W	2·0	84 4	69 1	74	3	TOTAL 0 29

Meteorological Observations taken at 8 A.M

DECEMBER, 1917.

Date.	Barometer. (corrected)	Wind. Direction.	Wind. Velocity per hour in miles.	Temperature. Maximum.	Temperature. Minimum.	Humidity.	Cloud Proportion.	Rainfall in inches.
1	30·054	W	3·2	82·0	65·0	85		
2	·026	W N W	1·5	81·5	63·0	67		
3	29·963	Calm	1·7	82·0	63·0	74		
4	30·012	N W	0·6	83·0	63·5	70		
5	·035	N W	1·6	80·5	63·0	71	2	
6	·056	N N E	2·7	80·0	62·5	64		
7	·018	N	2·2	79·0	63·0	67	3	
8	29·950	N N W	2·1	79·0	64·0	79	10	
9	·965	N	1·4	80·0	65·0	77	4	
10	·986	N E	1·0	83·5	66·5	73		
11	·936	W	1·7	82·5	64·0	74		
12	·961	Calm	1·7	81·5	63·0	76		
13	30·014	N W	1·8	80·0	59·0	72		
14	29·974	W N W	2·2	77·5	57·0	71		
15	30·006	Calm	1·6	77·5	58·0	67		*Nil*
16	29·973	N	1·1	78·0	58·0	63		
17	·995	N	0·9	79·0	59·5	66		
18	30·021	N N W	1·0	78·5	58·0	74		
19	·055	N N W	1·5	78·0	60·0	73		
20	·037	N N W	1·5	79·0	61·0	71		
21	·024	N W	1·2	82·0	63·0	76		
22	·057	N N W	2·2	79·0	59·0	74		
23	·031	N N W	3·1	74·0	56·0	67		
24	·022	N	2·5	76·0	57·5	69		
25	29·960	Calm	1·0	76·0	58·0	80		
26	·940	Calm	1·3	77·5	58·5	72		
27	·907	N W	0·9	80·0	58·0	74	6	
28	·922	Calm	1·1	79·0	59·5	80	4	
29	·967	N	1·0	78·0	61·0	78	1	
30	·977	N N W	2·0	79·0	62·0	78	7	
31	30·017	N W	2·2	78·5	62·0	80	9	
Mean	29·996	68N25°W	1·7	79·4	61·0	73	1	TOTAL *Nil*

ANNUAL SUMMARY, 1917.

Month.	Mean Pressure.	Wind. Mean Direction.	Wind. Mean Velocity.	Temperature. Mean Maximum.	Temperature. Mean Minimum.	Mean Humidity.	Mean Cloud Proportion.	Total Rainfall.
Jan.	30·053	42N23° W	1·3	78·7	59·1	73	1	*Nil*
Feb.	29·941	14N34° W	2·0	81·4	65·2	77	4	1·18
March	29·883	9S30° W	2·3	85·4	71·4	72	2	0·99
April	29·755	63S3° W	3·2	91·7	77·4	74	2	1·82
May	29·748	52S4° W	2·7	96·9	77·1	71	4	7·88
June	29·561	47S42° E	2·5	92·3	79·2	83	7	12·71
July	29·515	36S52° E	2·0	90·3	80·0	86	8	11·91
August	29·650	55S21° E	2·4	89 8	79·5	87	8	11·14
Sept.	29·650	43S67° E	2·0	90·9	79·1	85	7	7·98
October	29·780	45N78° E	2·0	90·5	77·8	81	4	13·83
Nov.	29·948	77N18° W	2·0	84·4	69·1	74	3	0·29
Dec.	29·996	68N25° W	1·7	79·4	61·0	73	1	*Nil*
Mean	29·790	...	2·2	87·6	73·0	78	4	TOTAL 69 73

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THE INDIAN ASSOCIATION FOR THE

DR. *Receipts and Expenditure during the*

	Rs.	As.	P.
To Subscription Account	691	0	0
,, Rent from Shops	2,892	0	0
,, Ripon Prof. Fund	5	0	0
,, H. H. Maharaja of Cooch Behar Prof. Fund ...	1,200	0	0
,, Dr. Sircar Memorial Fund	1,480	0	0
,, Interest Account, General Fund	7,090	6	8
,, ,, Ripon Prof. Fund ...	190	0	0
,, ,, Nikunja Garabini Prize Fund	17	8	0
,, ,, Woodburn Medal Fund ...	17	8	0
,, ,, Jatindra Chandra Prize Fund	19	4	0
,, Fees from students	8,938	0	0
,, Income Tax	1	10	10
,, Discount on Purchase of Govt. Securities ...	1,814	12	0
,, Bulletin Sale Account	9	2	0
,, Breakages Account	34	1	0
,, Donation Acc aunt	5,000	0	0
,, Provident Fund Account	905	7	11
,, Joy Kissen Mukherjee Gold medal ...	200	0	0
,, Deposit Account from Students	126	0	0
,, Floating balance in the Bank of Bengal on the 31st December, 1916	2.755	3	11
,, Cash in office, 31st December, 1916 ..	911	3	3
Total ...	34,298	3	7

Certified that the accounts for the year 1916 have been audited and found correct.

AMRITA LAL SIRCAR, L.M.S., F.C.S.,
Honorary Secretary.

I. C. BOSE,
Hony. Auditor.

CULTIVATION OF SCIENCE.

year ending 31st December, 1917. **Cr.**

	Rs.	As.	P.
By Govt. Securities 3½ per cent. purchased, General Fund	6.000	0	0
,, Commission Account (Ripon Prof. Fund) ...	1	6	0
,, ,, ,, (Nikunja Garabini Prize Fund)	0	3	0
,, ,, ,, (General Fund) ...	28	2	0
,, Observatory Account	188	4	3
,, Contribution to Provident Fund Account ...	185	15	11
,, Instruments purchased (General Fund) ...	1,371	6	7
,, Cooch Behar Lecturer	600	0	0
,, *Jatindra Chandra Prize*	18	13	0
,, Sir Richard Temple Medal	17	8	0
,, Nikunja Garabini Prize	17	8	0
,, Joy Kissen Mukerjee Gold Medal	51	0	0
,, Establishment Account	8,302	11	4
,, Library Account (Books, &c.)	240	6	3
,, Workshop Materials	8	2	0
,, ,, Petty charges	18	8	0
,, Electric Installation	898	7	6
,, Furniture Account	171	8	6
,, Taxes (Municipal Bills, &c.)	1,553	7	6
,, Lecture Charges	1,017	12	0
,, Botany class charges	1,919	5	3
,, Charges General	1,543	12	6
,, Lighting Charges (Kerosene oil, &c.) ...	5	7	0
,, Printing charges	1,784	7	6
,, Postage Stamp Account	172	8	6
,, Gas	178	5	0
,, Electric Light	364	4	0
,, Provident Fund	225	0	0
,, Building Re-construction Account	471	8	9
,, Plants Account	10	14	0
,, Research Scholarship, Physics	300	0	0
,, Floating Balance in the Bank of Bengal on the 31st December, 1917	5,447	1	5
Cash in Office, 31st December, 1917 ...	1,184	7	10
Total Rs.	34,298	3	7

THE INDIAN ASSOCIATION FOR THE

Dr. *Balance Sheet as on*

	Rs.	As.	P.
To Govt. Securities $3\frac{1}{2}\%$ in Custody of the Bank of Bengal (General Fund)	2,10,400	0	0
" Do. Do. (Ripon Prof. Fund) ...	6,000	0	0
" Do. Do. Nikunja Garabini Fund ...	500	0	0
" Value of land and old building	31,680	11	9
" Lecture Hall and Gallery	23,465	5	3
" Vizianagram Laboratory	40,900	14	0
" Range of Shops (East side)	2,516	10	9
" Range of Shops (West side)	2,308	5	0
" Darwan's Room	303	13	9
" Servants' Quarters	1,024	0	0
" Observatory	3,104	14	3
" Bonus, Provident Fund Account ...	1,422	0	0
" Contribution to Provident Fund Account ...	813	0	5
" Scientific Instr. Acct. (K.K. Tagore's Fund) ...	25,000	0	0
" Scientific Instruments Acct. (General Fund) ...	24,903	6	7
" Botanical Instrument Account	1,041	4	3
" Library Account (Books, &c.)	15,728	7	4
" Tools and Implements Account	161	12	3
" Workshop Instruments	1,781	12	6
" Sir Richard Temple Medal Account ...	227	8	8
" Premium Account (Ripon Prof. Fund) ...	41	14	0
" Commission Account (Ripon Prof. Fund) ...	43	3	5
" Do. Do. (Nikunja G. Fund) ...	3	7	0
" Income Tax Account (Ripon Prof. Fund) ...	0	10	2
" Suspense Account	380	5	3
" Cash in the Bank of Bengal, 31st December 1917	5,447	1	5
" Cash in office, 31st December 1917 ...	1,184	7	10
Total Rs.	4,00,384	15	10

CULTIVATION OF SCIENCE.

31st December, 1917. **Cr.**

	Rs.	As.	P.
By General Fund Account	3,46,368	4	11
,, Ripon Professorship Fund	10,830	0	0
,, H. H. the Maharaja of Cooch Behar Professorship Fund	18,210	0	0
,, Hare Professorship Fund	1,025	0	0
,, Victoria Professorship Fund	1,000	0	0
,, Dr. Sircar Memorial Fund	9,406	8	0
,, Father Lafont Memorial Fund	15	0	0
,, Deposit from Students	356..	0	0
,, Breakage Account	65	11	0
,, Provident Fund Account	2,198	8	9
,, Woodburn Medal Fund	500	0	0
,, Joy Kissen Mukerjee Medal Fund ...	4,190	0	0
,, Nikunja Garabini Prize Fund	500	0	0
,, Jatindra Chandra Prize Fund	550	0	0
,, Interest Account (Ripon Prof. Fund) ...	4,860	9	10
,, ,, ,, (Nikunja Garabini Prize Fund)	97	5	8
,, ,, ,, (Woodburn Medal Fund) ...	211	8	0
,, Interest Account Jatindra Chandra Prize ...	0	7	0
Total Rs.	4,00,384	15	10

Certified that the accounts for the year 1916, has been audited and found corrected.

AMRITA LAL SIRCAR, L.M.S., F.C.S.,
Hony. Secretary.

I. C. BOSE,
Hony Auditor.

The Indian Association for the Cultivation of Science.

(210, Bow-Bazar Street.)

Established 1876.

The OBJECT of the Institution is the Cultivation and diffusion of the Physical Sciences.

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1. The Library shall be kept open from 11 A.M. to 6 P.M. daily, excepting Sundays and other holidays.

2. The Library shall be generally for the use of Members of the Association; but outsiders on proper introduction shall be allowed inside the Reading Room to study and refer to any books and serials, provided they pay an annual subscription of Rs. 6/- only.

3. The Members shall have the privilege of taking away books and serials from the Library on proper receipt.

4. Members shall be allowed to take two volumes at a time; the regular teaching staff and the advanced research workers shall have the privilege of taking out six volumes at a time.

5. Books taken out may be kept, if required, for one month, and serials for fifteen days only. If during the time the books and serials taken out are required by other members, a notice to that effect will be sent by the Librarian to the borrower.

6. Books and serials which are constantly required for reference should not be taken out; but if urgently required they may be issued, provided the borrower undertakes to return them within two days. All such volumes shall be marked with an asterisk on the cover or the title page as well as in the Library catalogue.

7. No new books shall be lent out before the expiration of one month after their receipt in the Library.

8. Pamphlets, serials and papers of a similar nature shall not be issued until they are bound.

9. A register of books issued shall be kept by the Librarian, in which shall be entered the name, address and signature of the borrower and the dates of issue and return.

10. When the borrower does not come in person a receipt may be sent to him to be returned after signature.

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* Passed at the seventy-sixth Meeting of the Committee of Management, held under the Presidency of Sir Gooroo Das Banerjee, Kt., M.A., D.L., Ph. D., Vice-President, on Friday, the 28th September, 1917.

WOODBURN RESEARCH MEDAL.

(Gold Medal.)

1904.

Dr. Sarasi Lal Sarkar, M.A.—for his Research on Crystalline Copper Ferrocyanides, a summary of which was published in the Report of the year 1902.

1913.

Mr. C. V. Raman, M.A.—for his Researches on General Physics which appeared in several Bulletins of the Association.

1917.

Prof. T. K. Chinmoyanandam, M.A. (Hons.)—for his researches on General Physics which appeared in several Proceedings of the Association.

DR. MAHENDRA LAL SIRCAR RESEARCH MEDAL.

(Gold Medal.)

1917.

Dr. Sudhansukumar Banerjee, D. Sc., for his researches on Applied Mathematics which appeared in several Proceedings of the Association.

Medallists and Prize Holders.

Physics and Chemistry.

In order of merit.

1879.

Scholarship of Rs. 10 per month for one year.

Charu Chandra Sircar——Scholarship, Joykissen Prize, and Silver Medal.

Amulya Charan Mitra——Scholarship and Joykissen Prize.

Kishoree Mohun Sen Gupta——Scholarship, Joykissen Prize and Silver Medal.

Bhabadeb Chatterjee——Scholarship.

Amrita Lal Sircar——Scholarship.

1880.

Scholarship of Rs. 10 per month for one year.

Dina Nath Sanyal——Gold Medal, Books and Scholarship.
Braja Lal Mukherjee——Silver Medal, Books and Scholarship.
Bepin Behary Ghosh——Books and Scholarship.
Purna Chandra Chatterjee——Books and Scholarship.
Ishananda Bhowali——Scholarship.
Kishoree Mohun Gupta——Silver Medal.

1893.

Suresh Chandra Sarkar—Jatindra Chandra Pize.
Kiran Chandra Singh—Chaitanya Library Medal.
Girindra Nath Mukerjee—Sarat Kumar Ghosal Medal.

1894.

Hridaya Ranjan Sen Gupta—Jatindra Chandra Prize.
Sarat Chandra Mukerjee—Sarat Kumar Ghosal Medal.
Sardar Bechitra Sing (Ludhiana)—Chaitanya Library Medal.

1895.

Gopal Chandra Biswas—Jatindra Chandra Prize.
Bipin Behary Das—Sarat Kumar Ghoshal Medal.
Niranjan Sarkar—Chaitanya Library Medal.

1897.

Hari Charan Mukherji—Jatindra Chandra Prize.

1904.

Devendra Nath Chatterjee—Joykissen Mukherjee Gold Medal.
Tincoury De—Garabini Prize.
Natendra Lal De—Jatindra Chandra Prize.
Jatindra Nath Ganguli—Temple Prize.

1905.

Probodh Chandra Chatterjee—Joykissen Mukherjee Gold Medal.
Radhakanta Sen Gupta—Temple Silver Medal.
Chandra Bhushan Ray—Garabini Prize.
Manindra Nath Banerjee—Jatindra Chandra Prize.

1906.

Patit Paban De—Joykissen Mukherjee Gold Medal.
Krishna Kishore Kumar—Temple Silver Medal.
Satya Ranjan Sen—Jatindra Chandra Prize.
Mohit Chandra Ghosh—Garabini Prize.

1907.

Tulsi Prasad Mitra—Joykissen Mukherjee Gold Medal.
Subinaya Rai Chaudhury—Temple Silver Medal.
Nagendra Nath Chatterjee—Jatindra Chandra Prize.
ProbodhKumar Chandra—Garabini Prize.

1908.

Nauratan Lal Barma—Joykissen Mukherjee Gold Medal.
Manik Lal Mukerjee—Temple Silver Medal.
Manmatha Lal Sircar—Jatindra Chandra Prize.
Nilratan Dhar—Garabini Prize.

1909.

Santosh Kumar Banerjee—Joykissen Mukherjee Gold Medal.
Kartic Chandra Dhur—Temple Silver Medal.
Kunja Behary Gupta—Jatindra Chandra Prize.
Tincouri Acharjya—Garabini Prize.
Narendra Nath Bose of Commercial Analysis Class—A special prize was awarded for his regular attendance and satisfactory Analytical Work in Chemistry.

1910.

Apurba Kumar Sen—Joykissen Mukherjee Gold Medal.
Banbehari Burhal—Temple Siver Medal.
Panchanan Sen—Jatindra Chandra Prize
Gunasindhu Sirdar—Garabini Prize.

1911.

Devendra Lal Buxi—Joykissen Mukherjee Gold Medal.
Ramani Mohun Gupta—Temple Silver Medal.
Dhyanendra Nath Sircar—Jatindra Chandra Prize.
Dhirendra Nath Mukerjee—Garabini Prize.

1912.

Durga Das Gupta—Joykissen Mukherjee Gold Medal.
Harabilash Chatterjee—Temple Silver Medal.
Nripendra Nath Mukherjee—Jatindra Chandra Prize.
Lal Mohun Chatterjee—Garabini Prize.

1913.

Joyti Prakash Bose—Joykissen Mukherjee Gold Medal.
Sachchidananda Banerjee—Temple Silver Medal.
Pramatha Lal Sircar—Jatindra Chandra Prize.
Gangadhar Samanta—Garabini Prize.

1914.

Kshitish Prasad Chattopadhyaya—Joykissen Mukherjee Gold Medal.
Binay Krishna Bose—Temple Silver Medal.
Narayan Chandra Nath—Jatindra Chandra Prize.
Nirmal Chandra Bose—Garabini Prize.

1915.

Surendra Nath Chatterjee—Joykissen Mukherjee Gold Medal.
Nagendra Nath De—Temple Silver Medal.
Jugol Kishore Shome—Jatindra Chandra Prize.
Barendra Nath Mazumdar—Garabini Prize.

1916.

Siddheshwar Banerjee—Joy Kissen Mukherjee Gold Medal.
Kali Pada Bhaduri—Temple Silver Medal.
Narayan Chandra Bose—Jatindra Chandra Prize.
Jogi Prosad Chowdhury—Garabini Prize.

1917.

Manic Lal Das—Joykissen Mukherjee Gold Medal.
Profulla Chandra Nandi—Temple Silver Medal.
Bankim Chandra Roy—Jatindra Chandra Prize.

Botany Prize.

In order of merit.

1914.

II Year.

1st Prize { 1. Radha Raman Mitra,
2. Kshitish Prasad Chattopadhaya,
3. Panchoo Gopal Nandy,

1915.

II Year.

1. Profulla Kumar Banerjee,
2. Nagendra Nath De II,
3. Nanda Lal Ghosh.

I Year.

1. Jugal Kishore Chatterjee,
2. Jatil Chandra Ghosh,
3. Kali Sahay Mukherjee.

1916.

II Year.

1. Nripendra Nath Bhaduri,
2. Jagannath Gangopadhyaya,
3. Jatil Chandra Ghosh.

I Year.

1. Bishnoo Charan Mukherjee,
2. Kamal Bhusan Bose,
3. { Krishna Chandra Mitra,
Radha Benode Ghosh.

1917.

II Year.

1. Suprakash Sen Gupta.
2. Nogendra Nath Sen.
3. Pulin Behary Ghosh.

I Year.

1. Sudhir Kumar Chakraverty.
2. Sashadhar Goswami.
3. Sri Ranjan.